

# Development of 1/8-degree calibrated precipitation guidance from GEFS reforecasts

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# Reforecast refresher

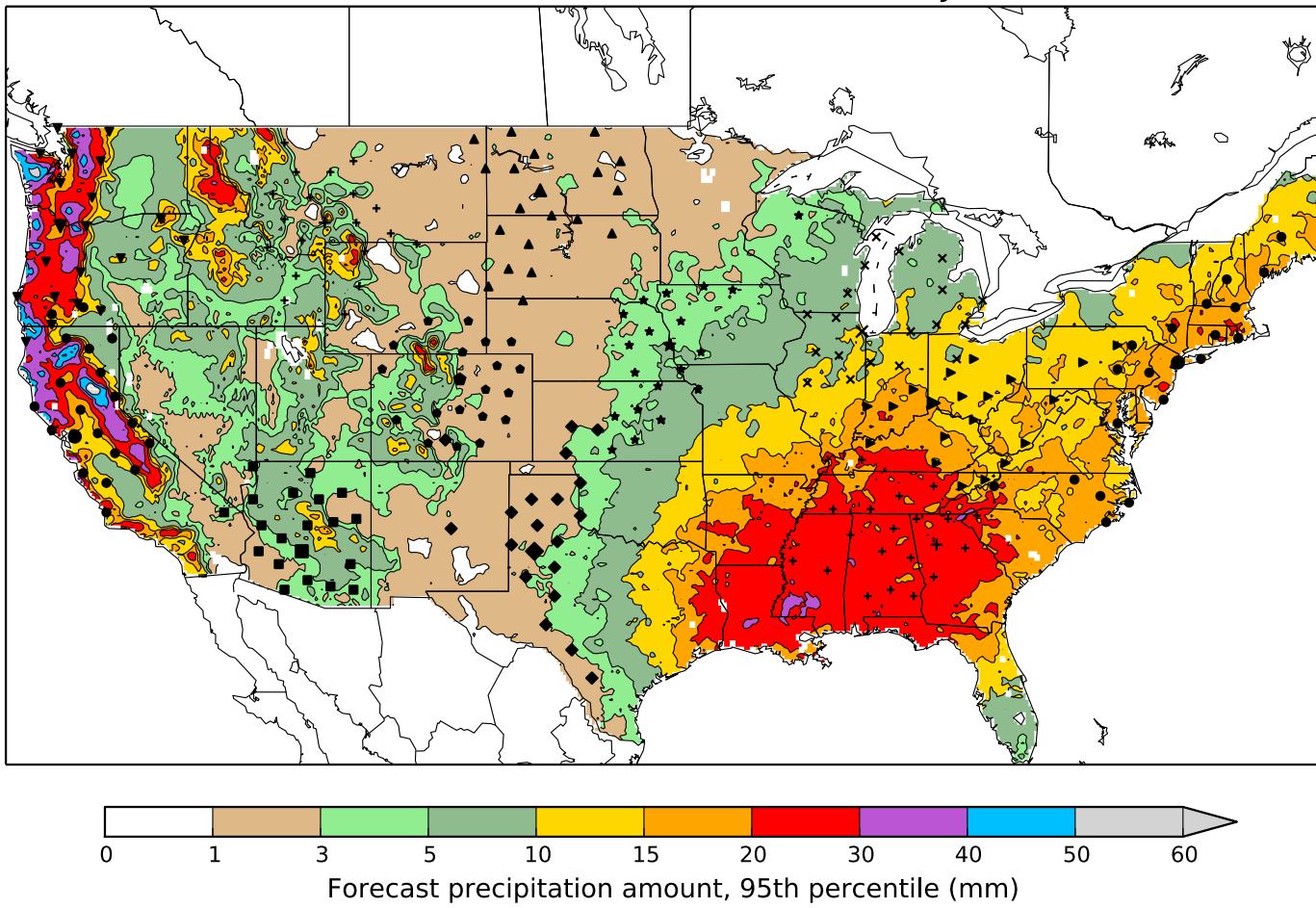
- We have reforecasts for the current version of the GEFS, 11 members daily from 1985-current.
  - Ref: <http://dx.doi.org/10.1175/BAMS-D-12-00014.1>
- Reasonably quality precipitation analysis data over CONUS extends back to 2002 (1/8-degree CCPA, and Stage-IV).
  - Ref: <http://dx.doi.org/10.1175/JHM-D-11-0140.1>
- Funded via small USWRP grant to develop reforecast-calibrated precipitation guidance at 1/8-degree and provide web graphics and access to grib files.
- Have frequently used “analog” method for post-processing in the past; form ensemble of observed data on dates when past forecast resembles current forecast. Can we improve on this?

# New developments

- Analog algorithm matches *point data* now, not patterns around a grid point.
  - This allows use of supplemental data locations for training purposes (next slide).
  - Finding analogs: 70% match of mean precipitation forecast, 30% match of precipitable water forecast.
  - Result: significant improvement in short-range PQPF skill and reliability in wintertime.
- Analog method's forecasts have some sampling noise, so where terrain is ~ even, we smooth probabilities with a Savitzky-Golay smoother before dissemination.

# Supplemental data locations

Supplemental (analysis grid) locations and 95th percentile of forecasts, 024 to 048-h forecast, Jan



Idea is to supplement training data at each grid point using  $n$  extra grid points that have similar observed climatology and similar forecast-observed relationships. In this plot, big symbol is where we're training, smaller symbol where we're supplementing training data.

In subsequent analog method plots shown,  $n=10$ .

# Smoothing the precipitation analyses

- Savitzky-Golay (S-G) filter used. For more details, see:
  - <http://research.microsoft.com/en-us/um/people/jckrumm/SavGol/SavGol.htm>
  - <http://www.wire.tu-bs.de/OLDWEB/mameyer/cmr/savgol.pdf> (good tutorial)
  - *Numerical Recipes* text.
- I coded up the S-G filter with a window size of 9 and using 3<sup>rd</sup>-order polynomial fitting.

# Savitzky-Golay filter

- designed to preserve amplitudes, unlike more common  $n \times n$  block smoothers

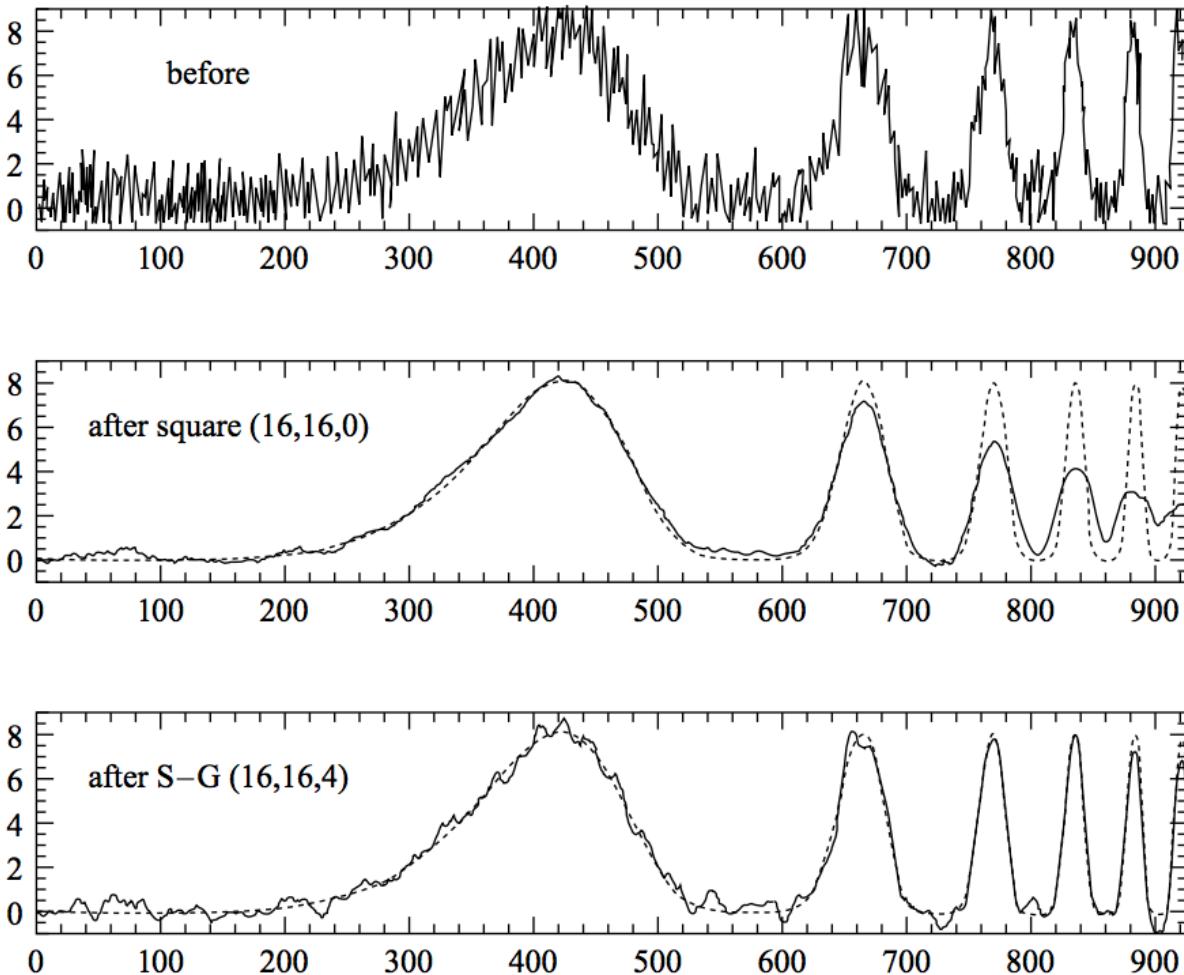


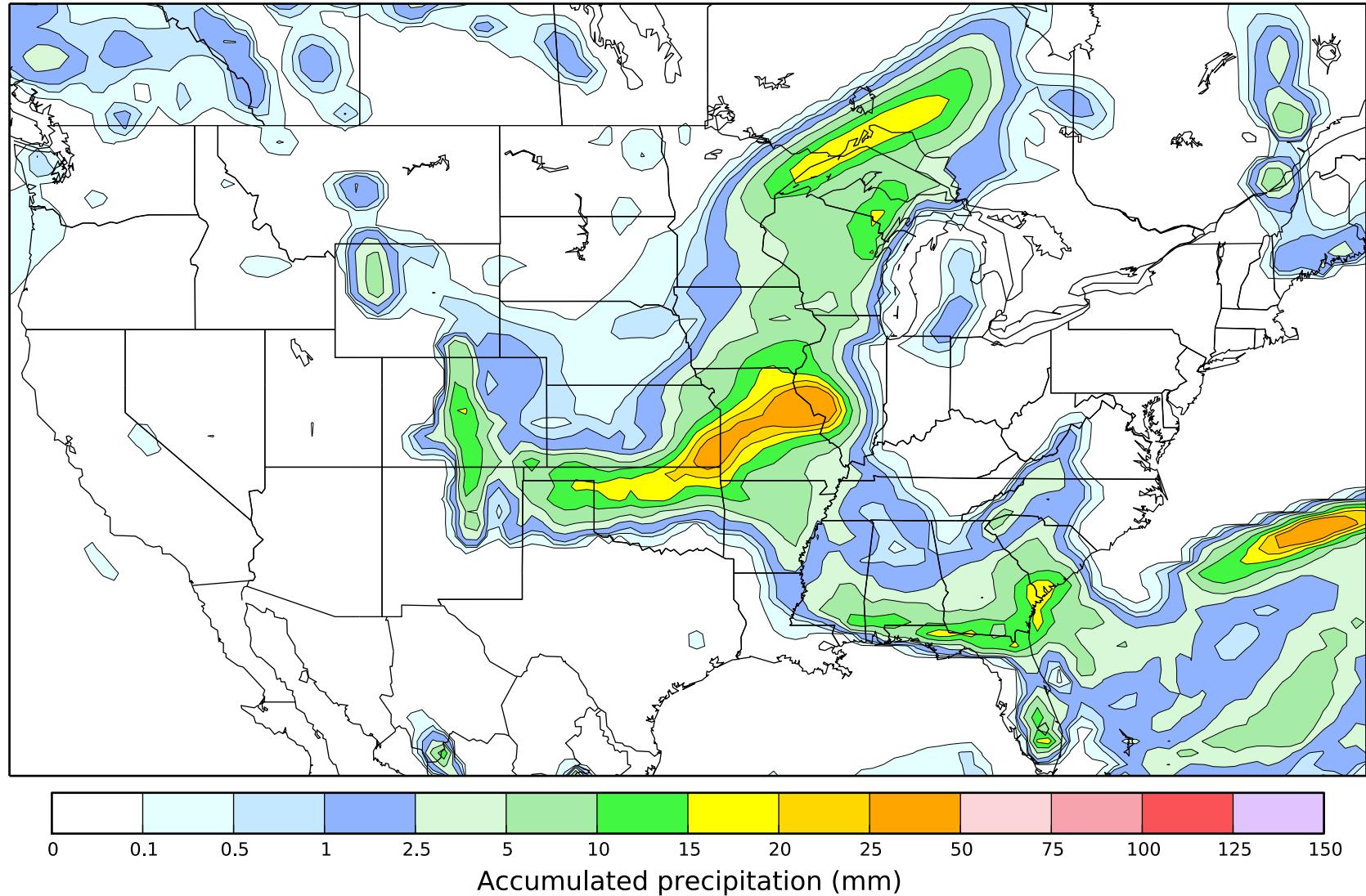
Figure 14.8.1. Top: Synthetic noisy data consisting of a sequence of progressively narrower bumps, and additive Gaussian white noise. Center: Result of smoothing the data by a simple moving window average. The window extends 16 points leftward and rightward, for a total of 33 points. Note that narrow features are broadened and suffer corresponding loss of amplitude. The dotted curve is the underlying function used to generate the synthetic data. Bottom: Result of smoothing the data by a Savitzky-Golay smoothing filter (of degree 4) using the same 33 points. While there is less smoothing of the broadest feature, narrower features have their heights and widths preserved.

# Undesirable aspect of Savitzky-Golay smoother?

- Detail in areas of complex terrain also smoothed out, too, perhaps inappropriately.

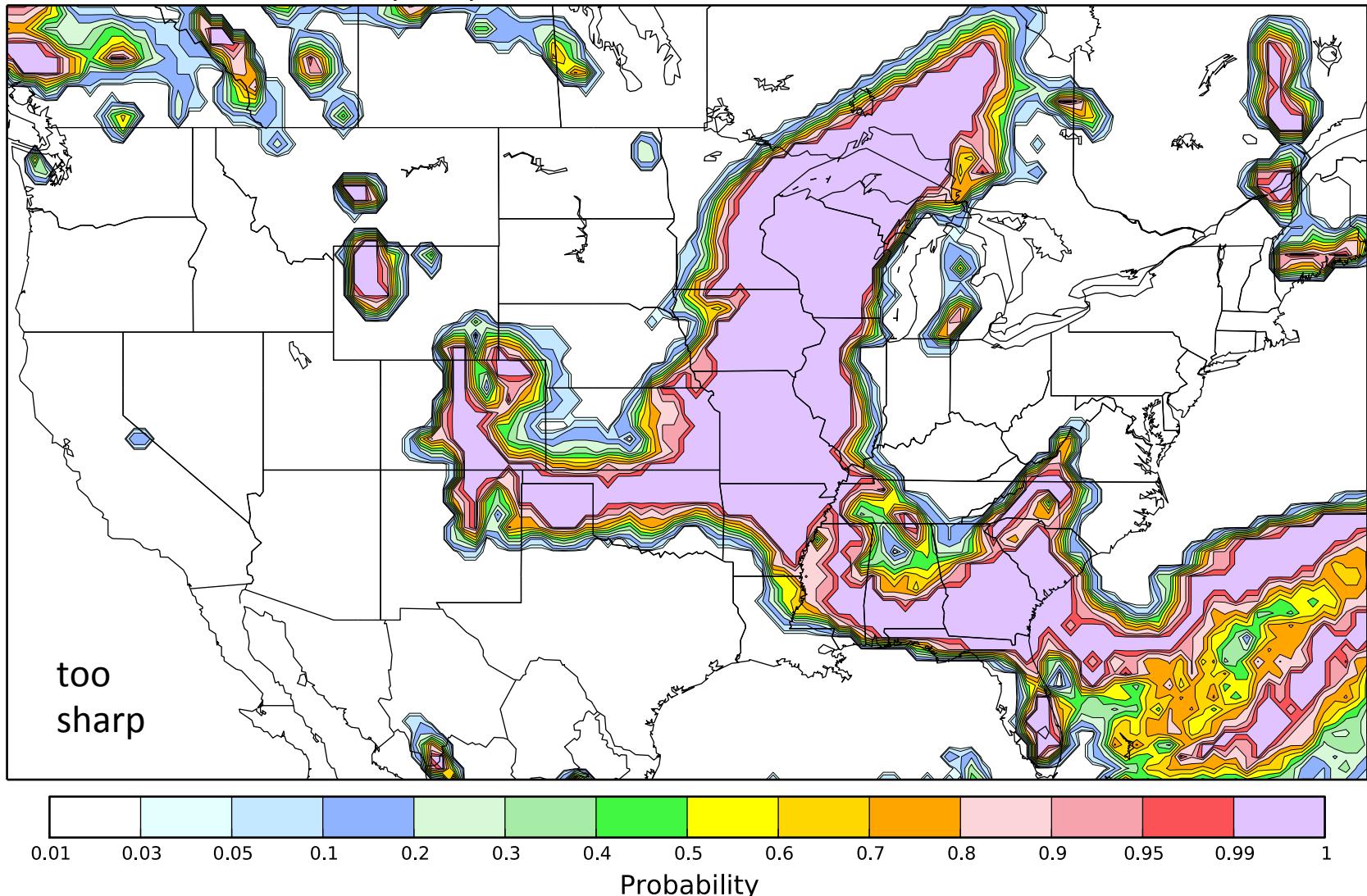
# Example: raw ensemble mean forecast

(a) 012-024-h raw mean forecast, initialized 2014060700, valid 2014060800



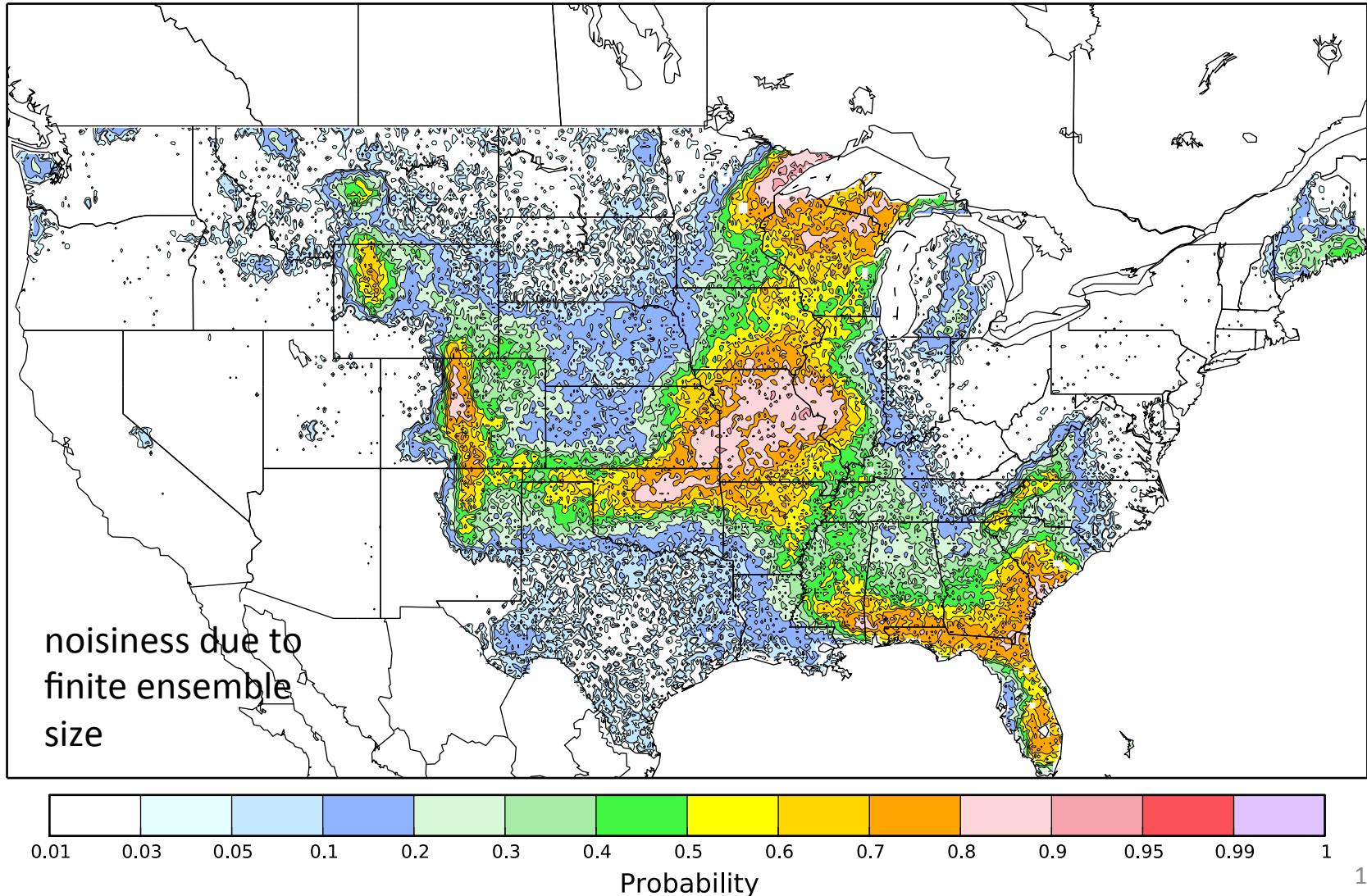
# Example: raw probabilities from ensemble

(c) 012-024-h raw  $P(\text{precip} > 1 \text{ mm})$ , initialized 2014060700, valid 2014060800



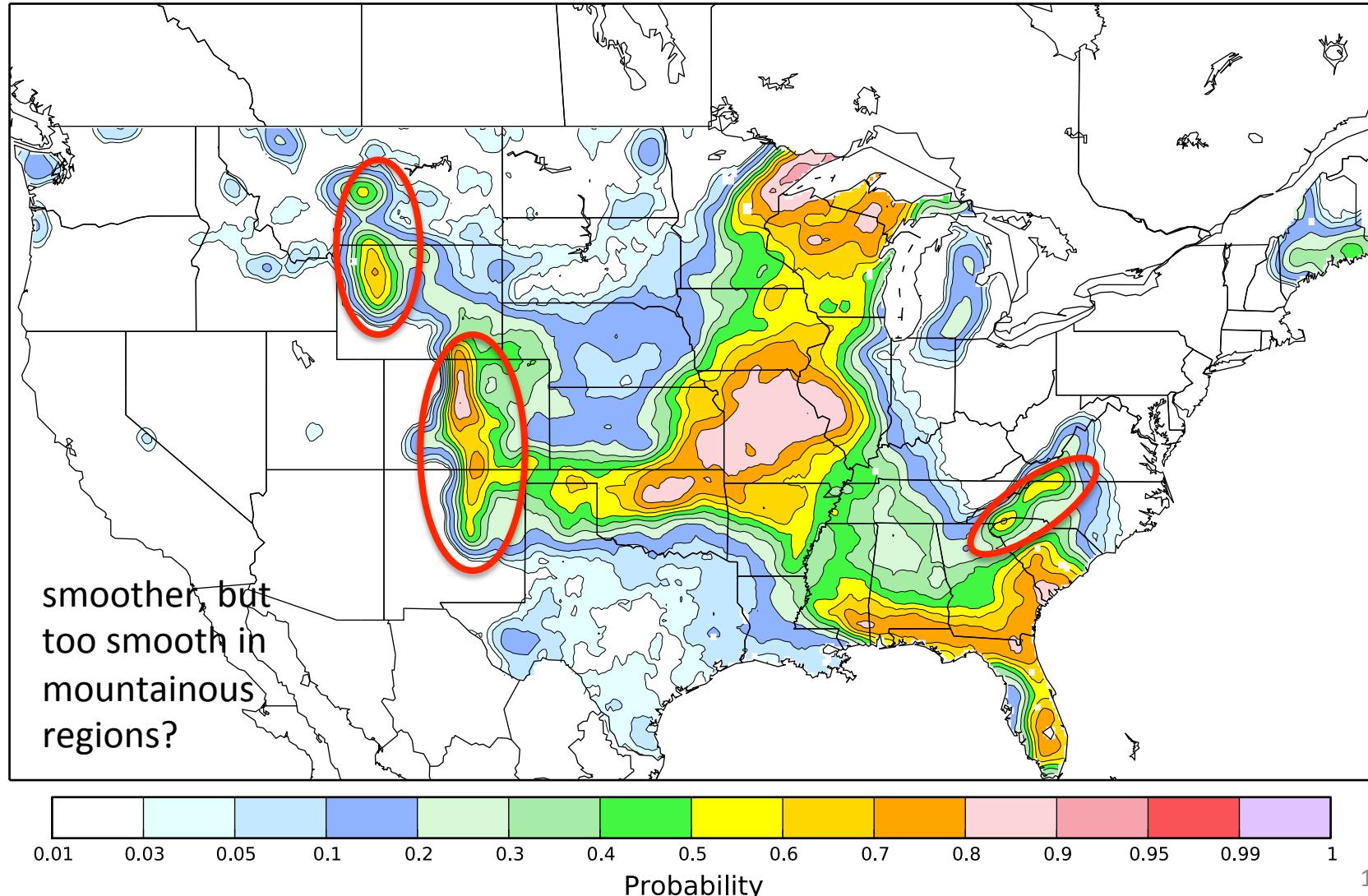
# Example: analog probabilities, unsmoothed

012-024-h raw calibrated  $P(\text{precip} > 1 \text{ mm})$ , initialized 2014060700, valid 2014060800



# Analog probabilities after domain-wide Savitzky-Golay filtering

012-024-h (S-G smoothed) calibrated P(precip > 1 mm), initialized 2014060700, valid 2014060800

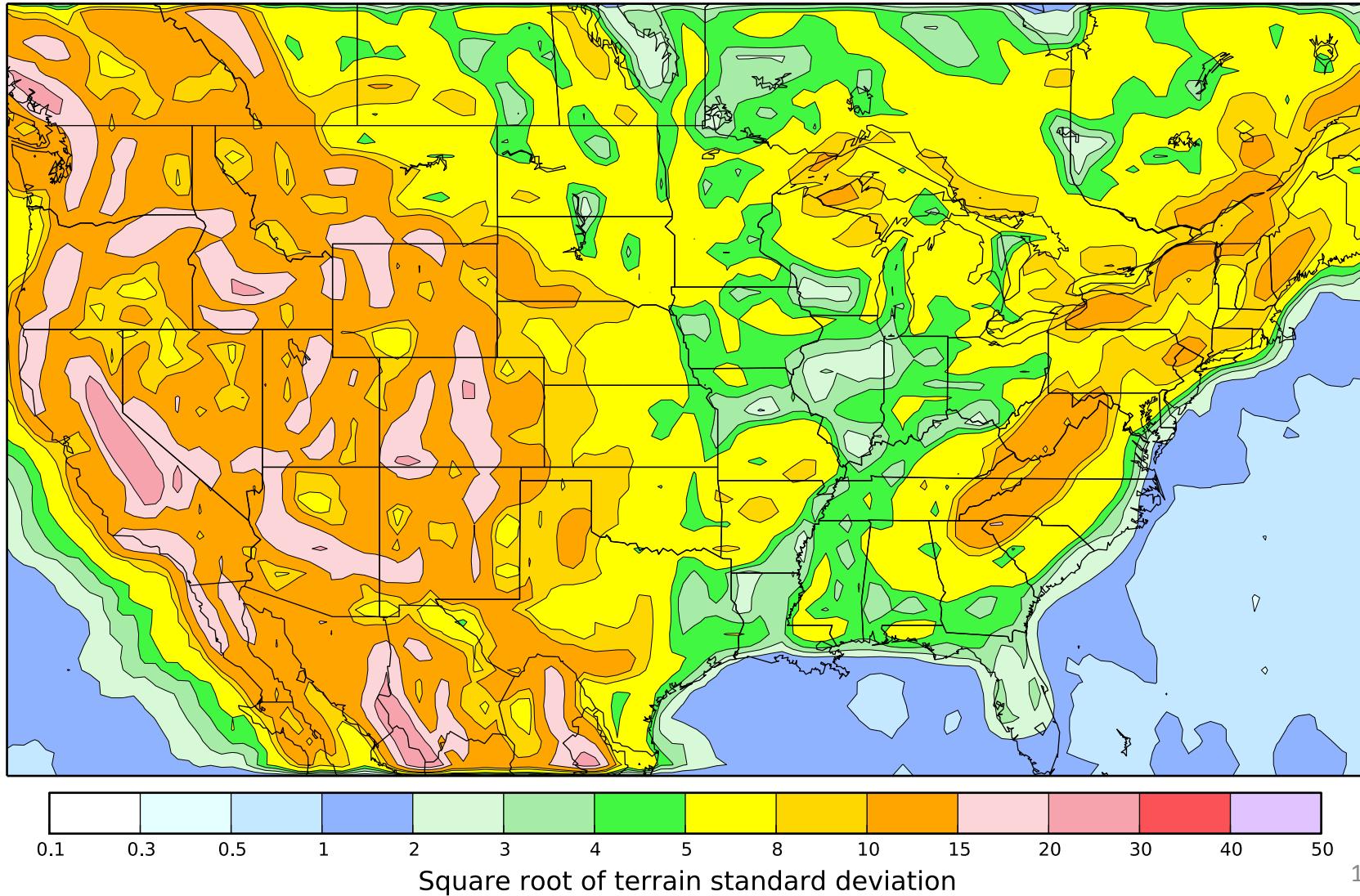


# Tentative solution: weight smoothed S-G even terrain, raw analog in complex terrain

- Specifically, compute standard deviation  $\sigma$  of terrain elevation in 3x3 box around each forecast grid point (1/2-degree grid).
- Weight of raw forecast:
  - = 0.8 if  $\sqrt{\sigma} > 18$
  - =  $0.2 + (\sqrt{\sigma}-8) / 16.667$  if  $8 \leq \sqrt{\sigma} \leq 18$
  - = 0.2 if  $\sqrt{\sigma} < 8$

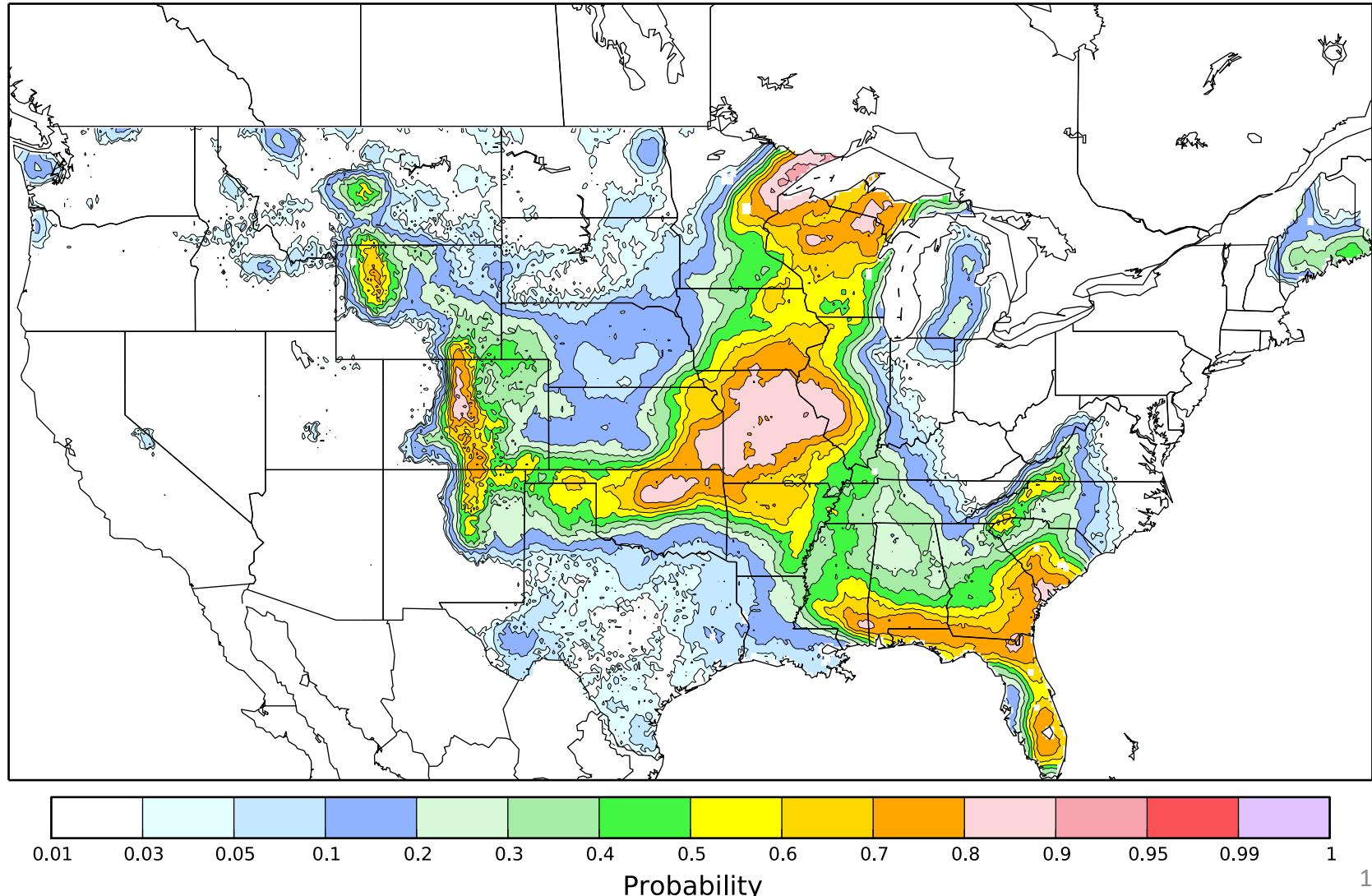
# $\sqrt{\sigma}$ as determined from $\sim \frac{1}{2}$ degree terrain elevation data

(f) Terrain square root of standard deviation



# Partially S-G smoothed analog probabilities based on terrain roughness

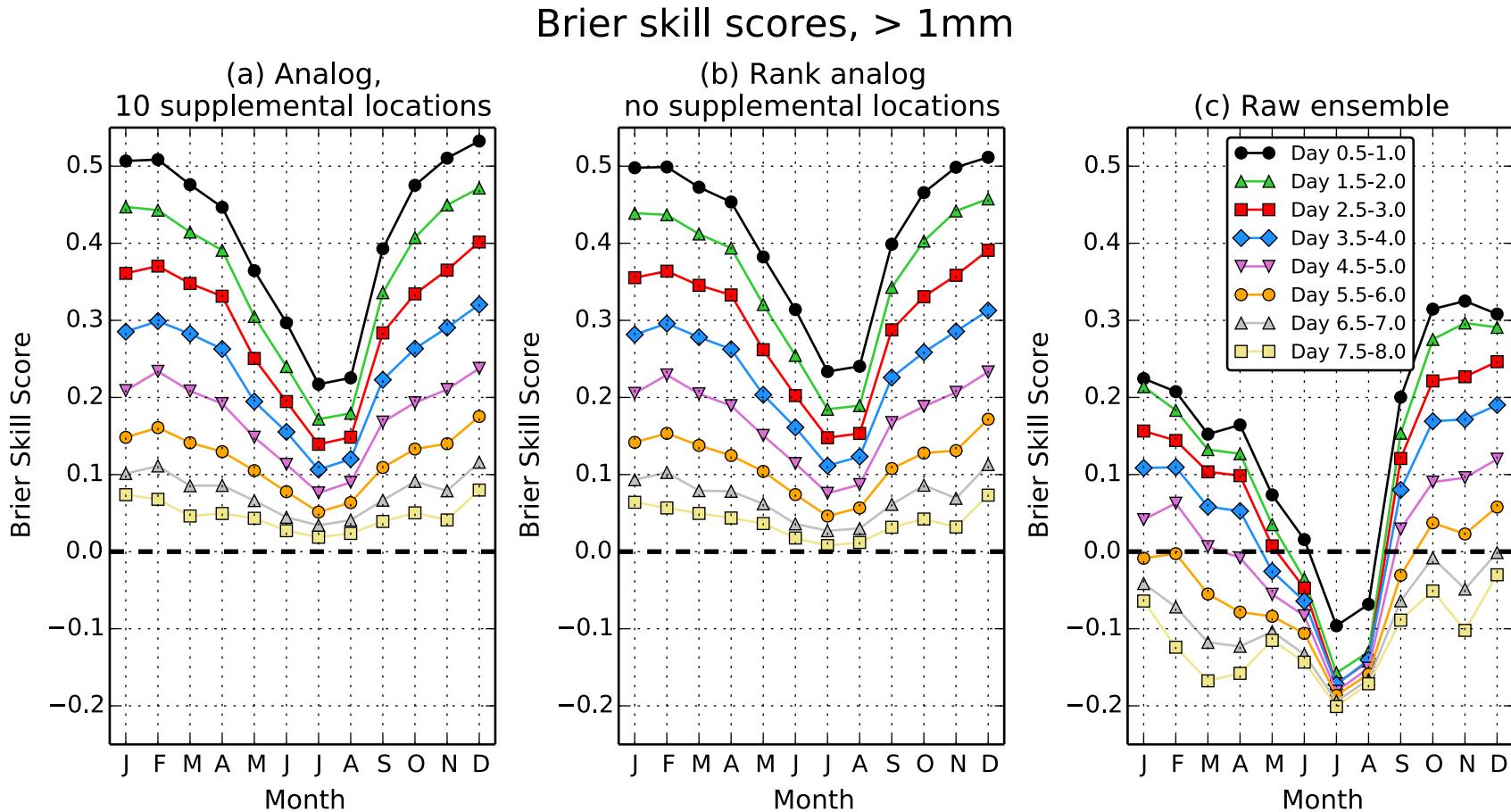
(b) 012-024-h calibrated  $P(\text{precip} > 1 \text{ mm})$ , initialized 2014060700, valid 2014060800



# Skill and reliability of analog forecasts

- We compare three methodologies:
  - Analog method based on point data; uses 10 additional locations as extra training samples, multiplying sample size for finding analogs by 10. Smoothed with S-G smoother as described. 70% precip, 30% pwat in choosing analogs.
  - Rank analog method using pattern match in surrounding region; no supplemental locations used. 70% precip, 30% pwat in choosing analogs.
  - Raw probabilities from 11-member ensemble relative frequency.

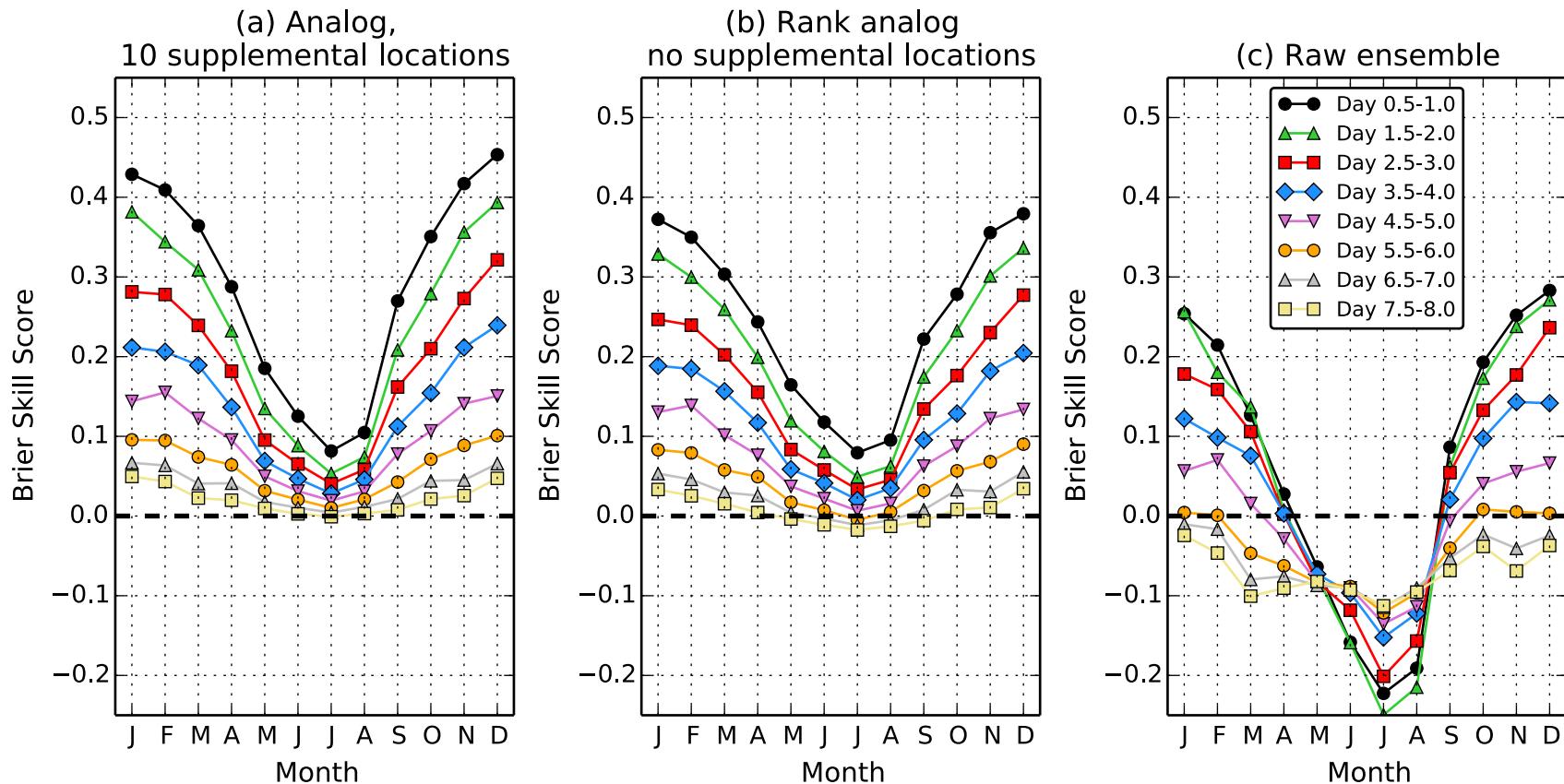
# Skill of (unsmoothed) analog forecasts using supplemental locations



for light precip, not much improvement from using additional supplemental training samples.

# Skill of (unsmoothed) analog forecasts using supplemental locations

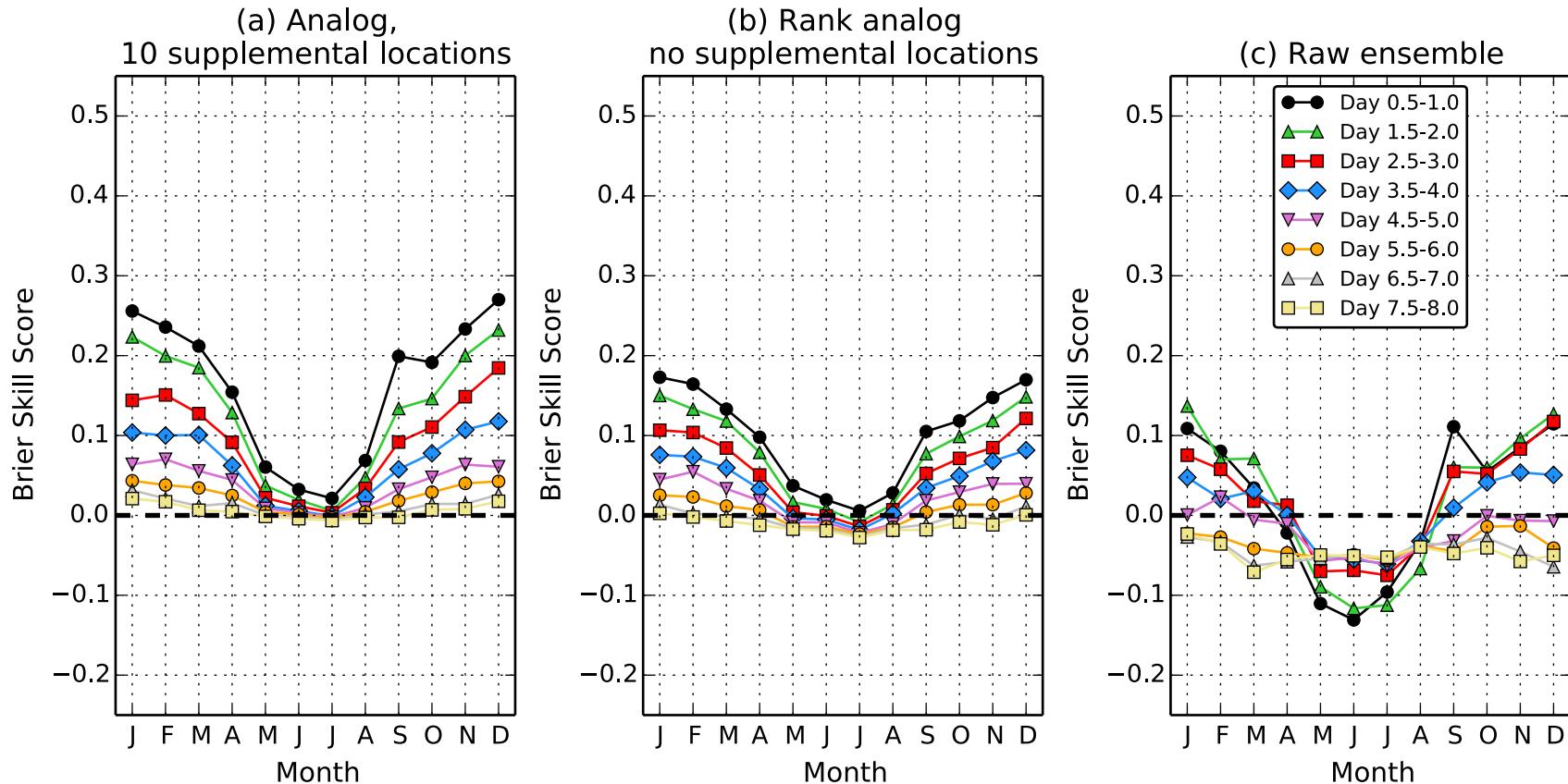
Brier skill scores, > 10mm



now we see cool-season benefit from use of supplemental locations in analog.

# Skill of (unsmoothed) analog forecasts using supplemental locations

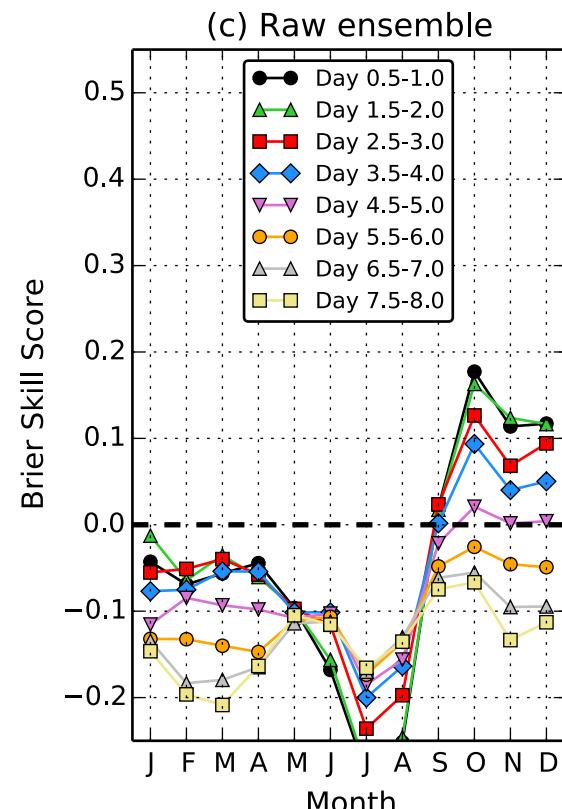
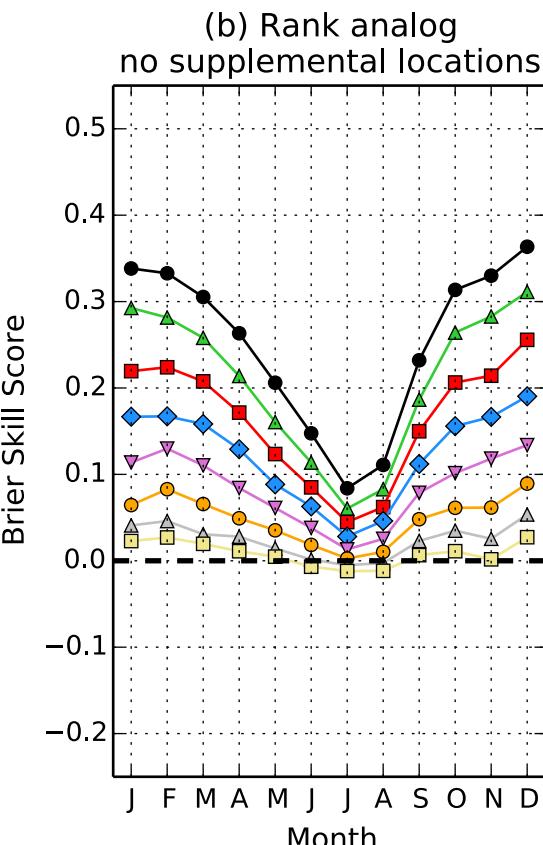
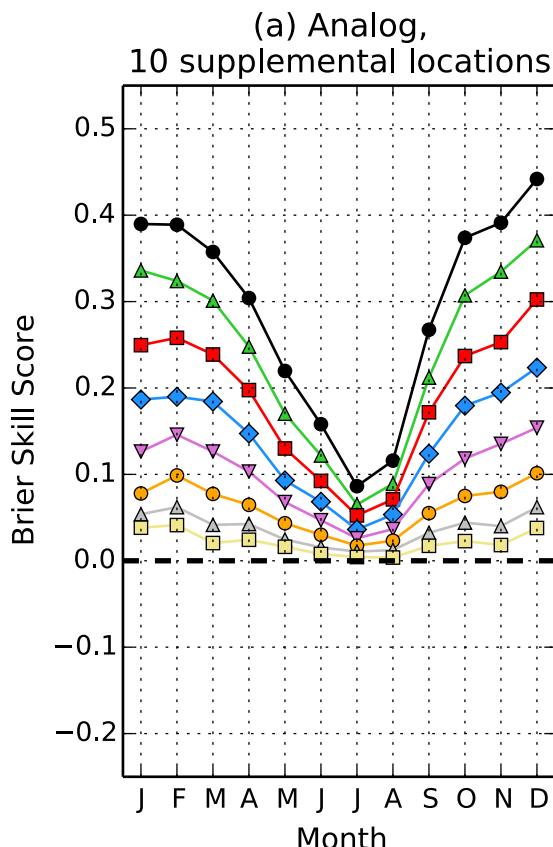
Brier skill scores, > 25mm



Again, larger sample size with supplemental locations particularly helpful for uncommon events

# Skill of (unsmoothed) analog forecasts using supplemental locations

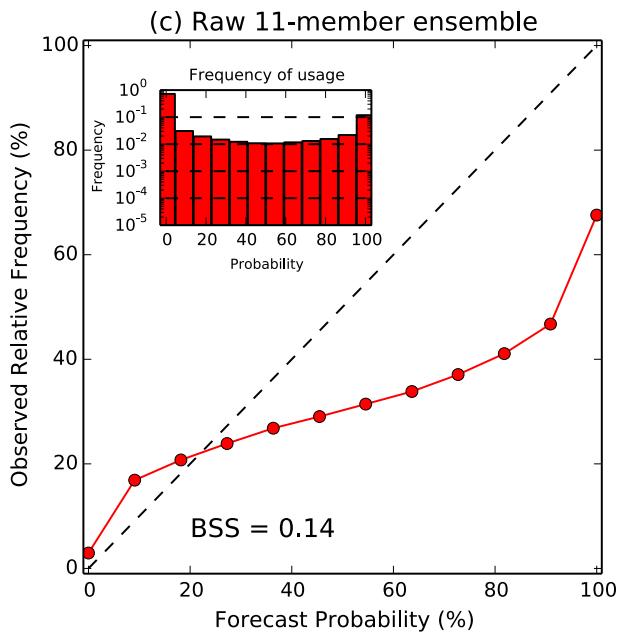
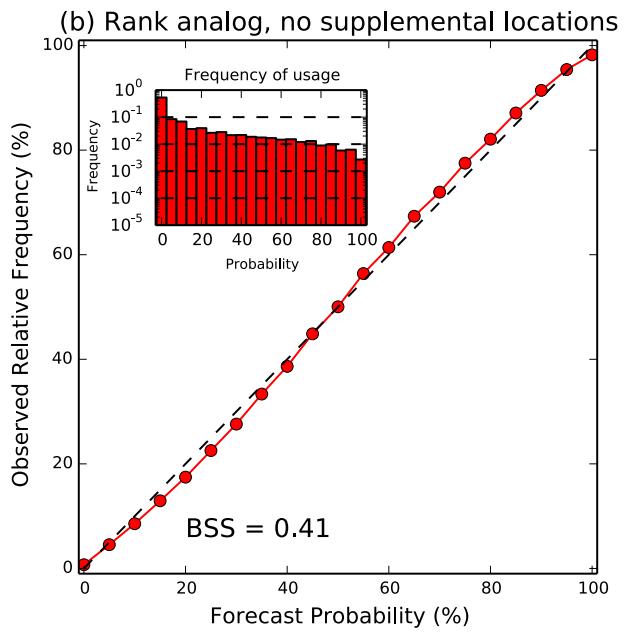
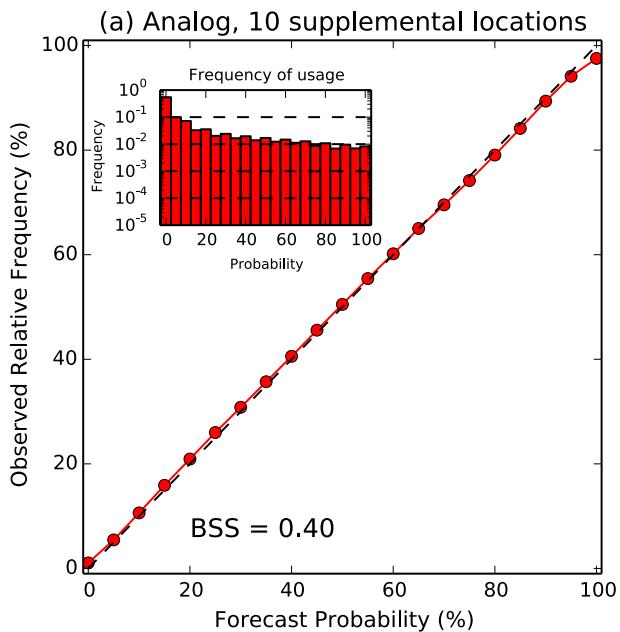
Brier skill scores, > q95



q95 refers to the 95<sup>th</sup> percentile of the climatological distribution, determined separately for each grid point and each month.

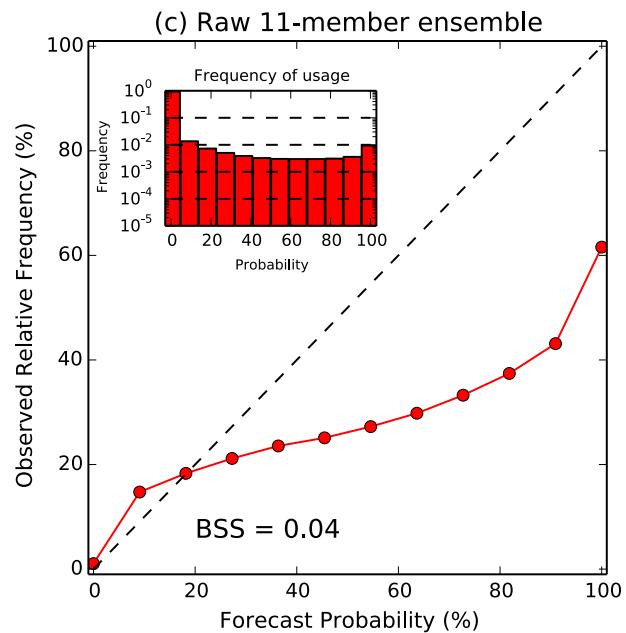
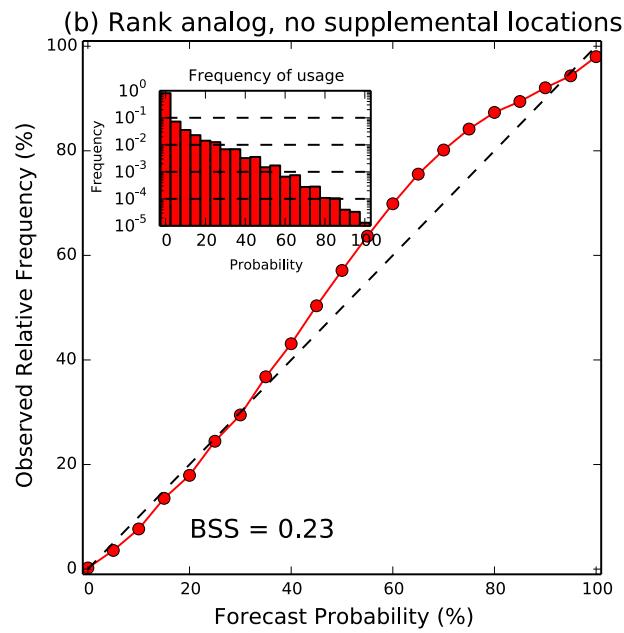
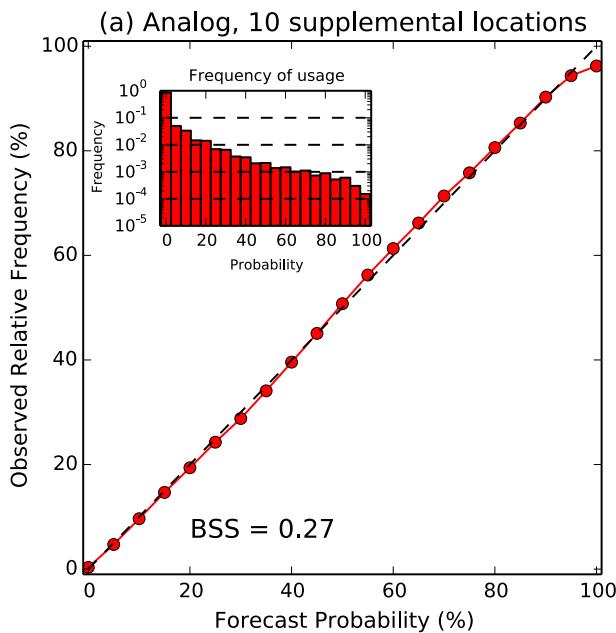
# Reliability, 12-24 h, > 1 mm

Reliability for 012-024-h, > 1mm



# Reliability, 12-24 h, > 10 mm

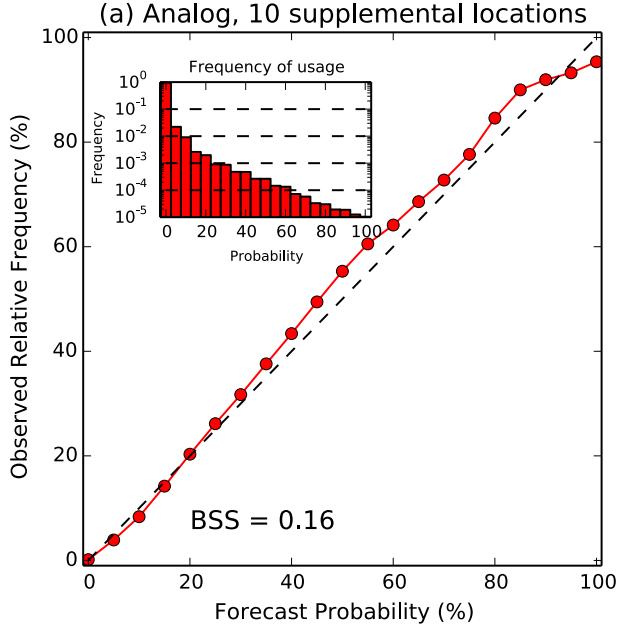
Reliability for 012-024-h, > 10mm



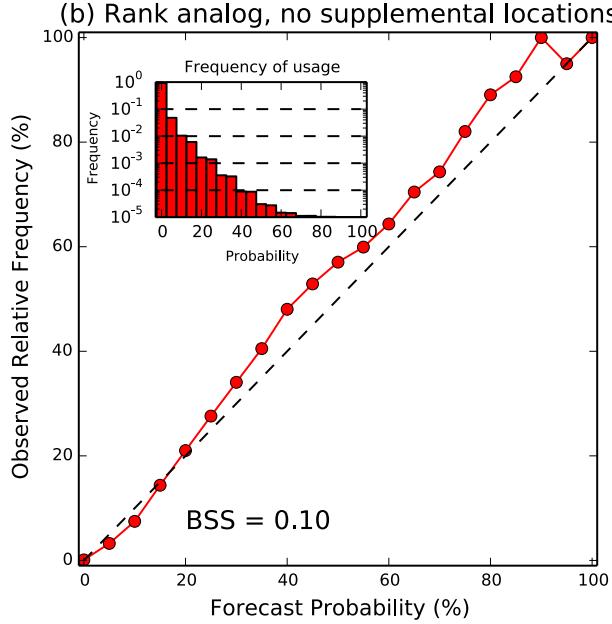
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Reliability for 012-024-h, > 25mm

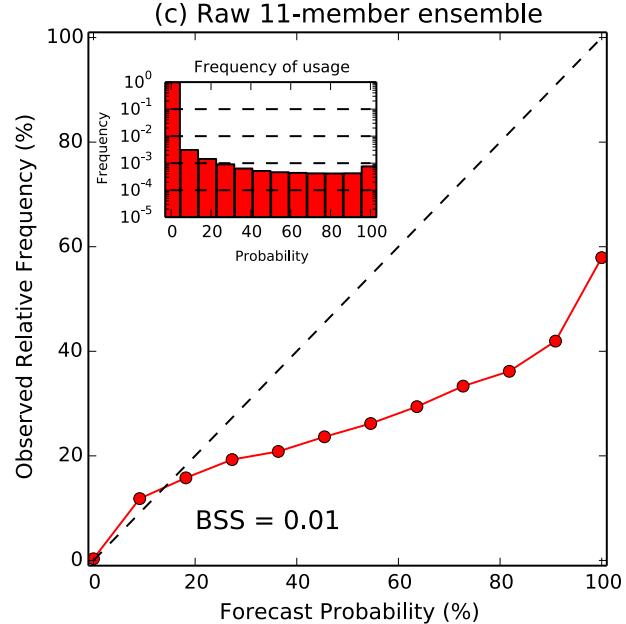
(a) Analog, 10 supplemental locations



(b) Rank analog, no supplemental locations

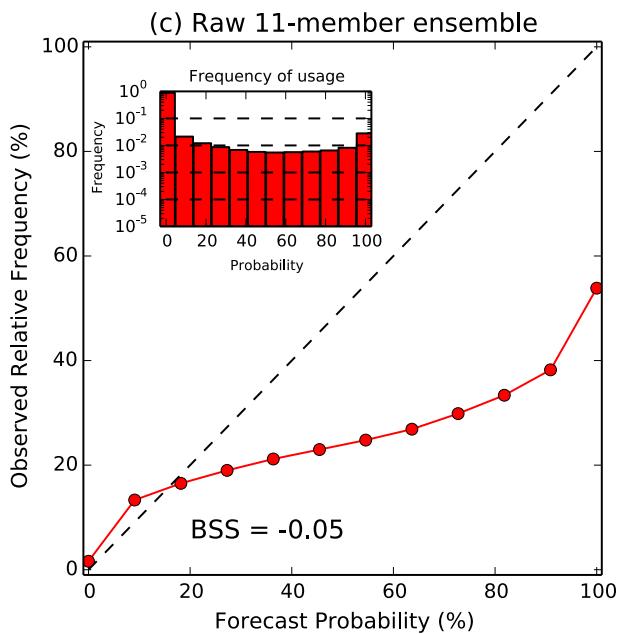
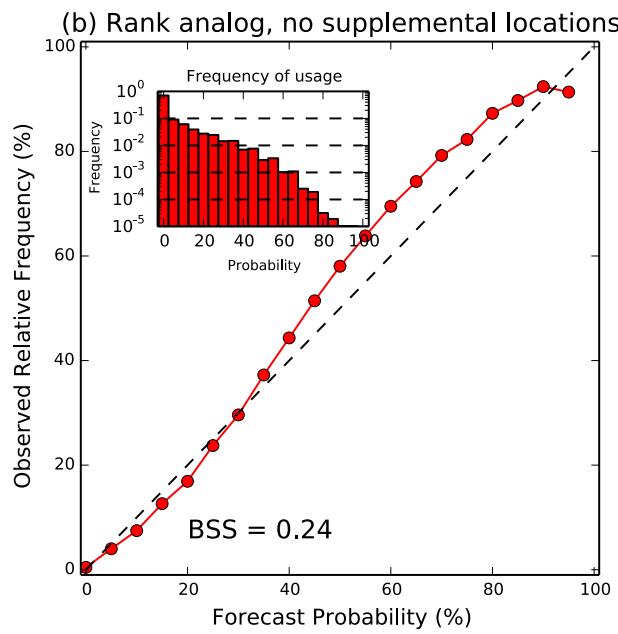
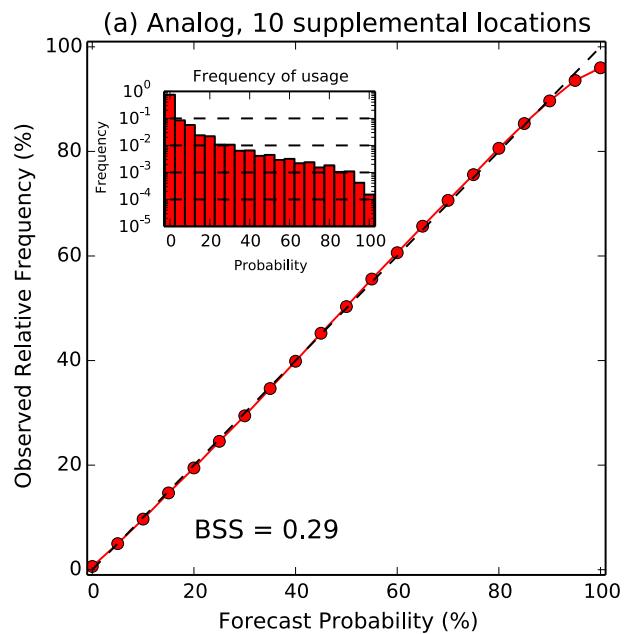


(c) Raw 11-member ensemble



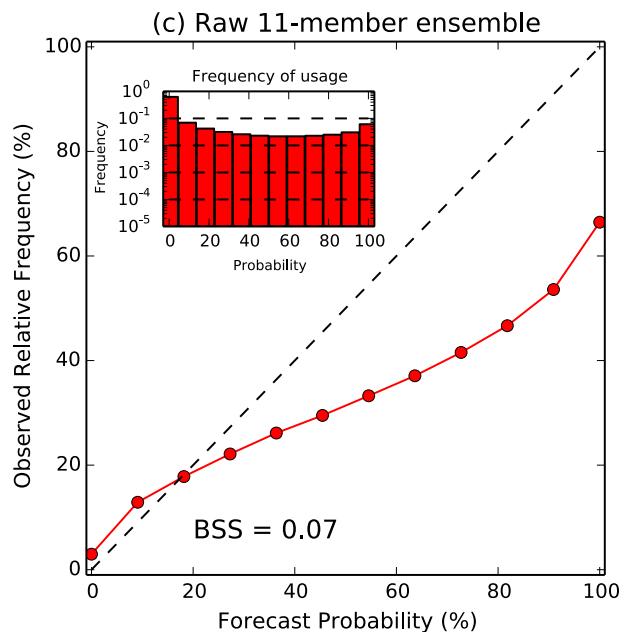
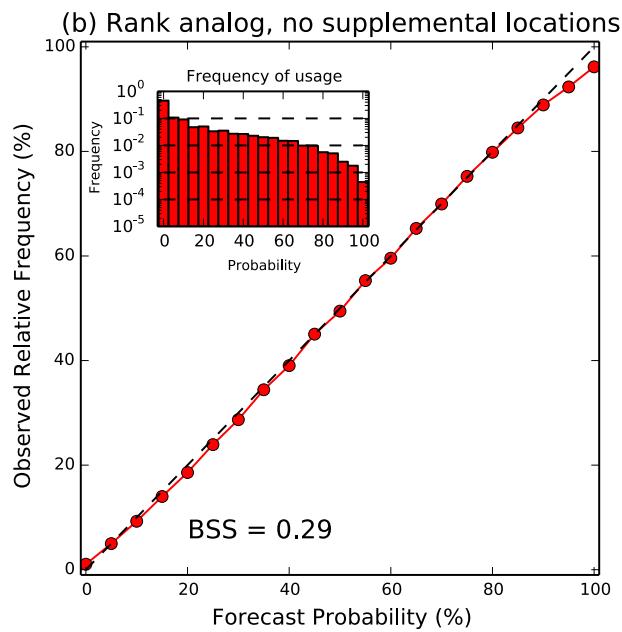
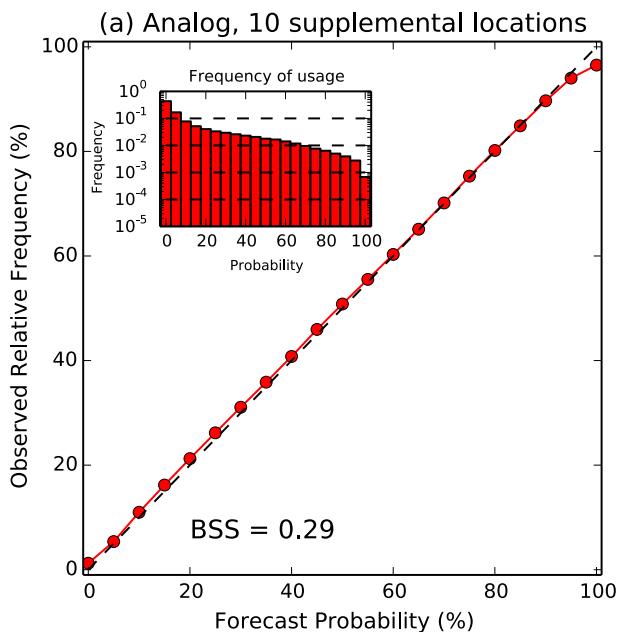
# Reliability, 12-24h, > 95<sup>th</sup> percentile

Reliability for 012-024-h, > q95



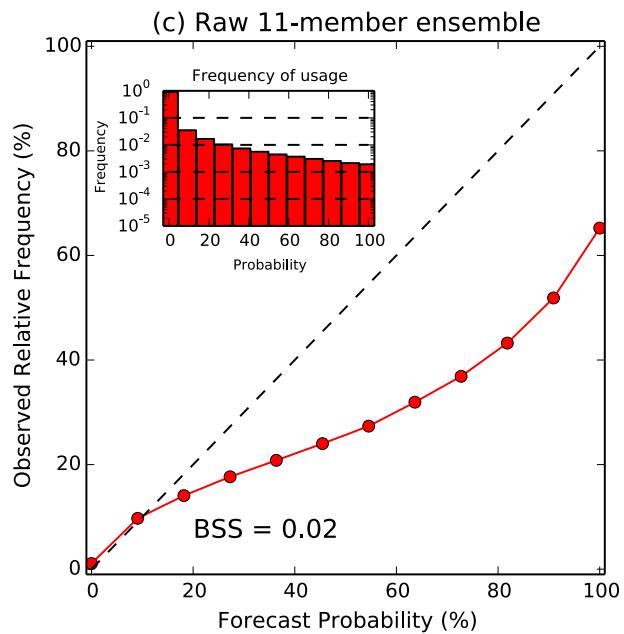
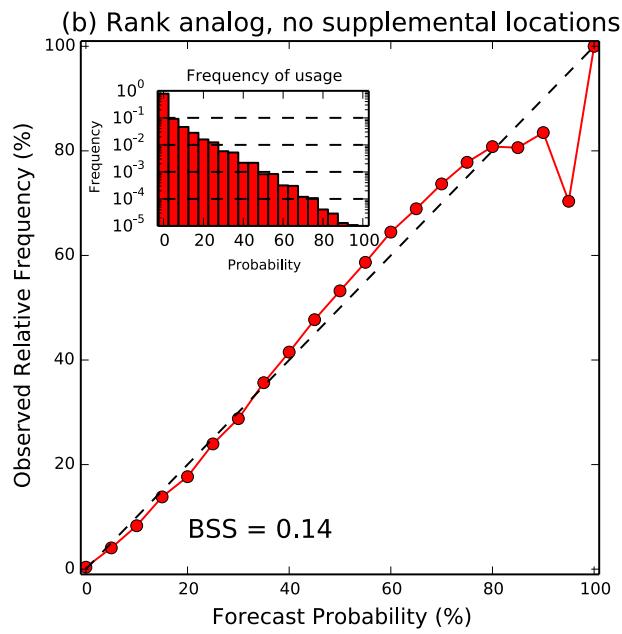
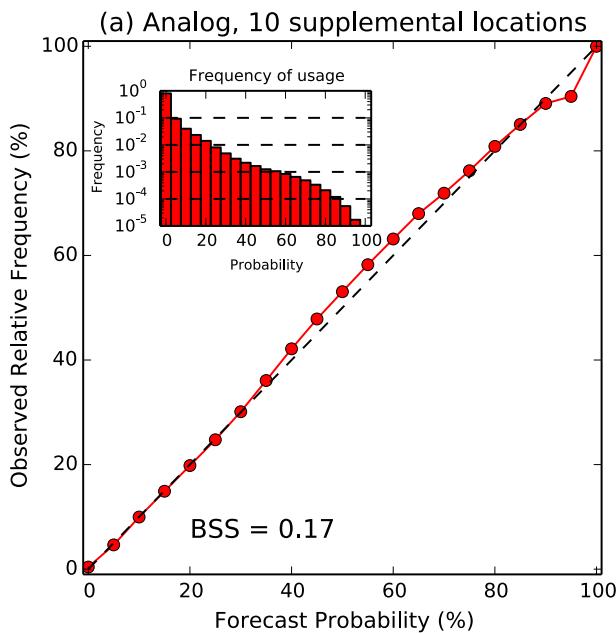
# Reliability, 60-72 h, > 1 mm

Reliability for 060-072-h, > 1mm



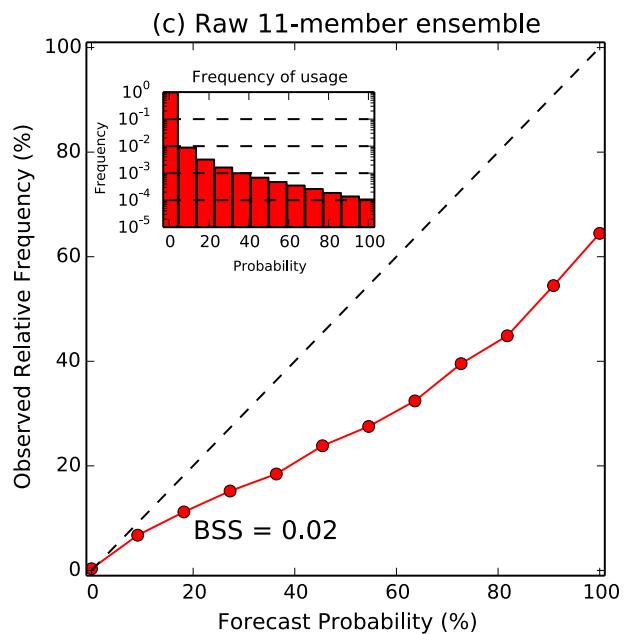
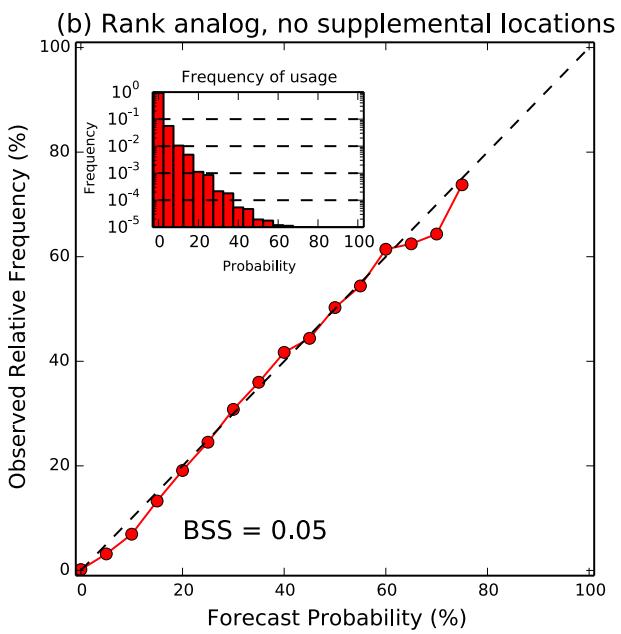
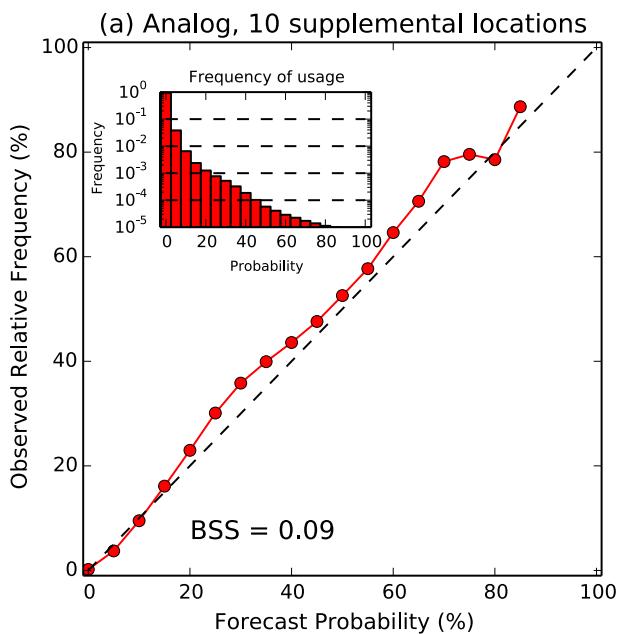
# Reliability, 60-72 h, > 10 mm

Reliability for 060-072-h, > 10mm



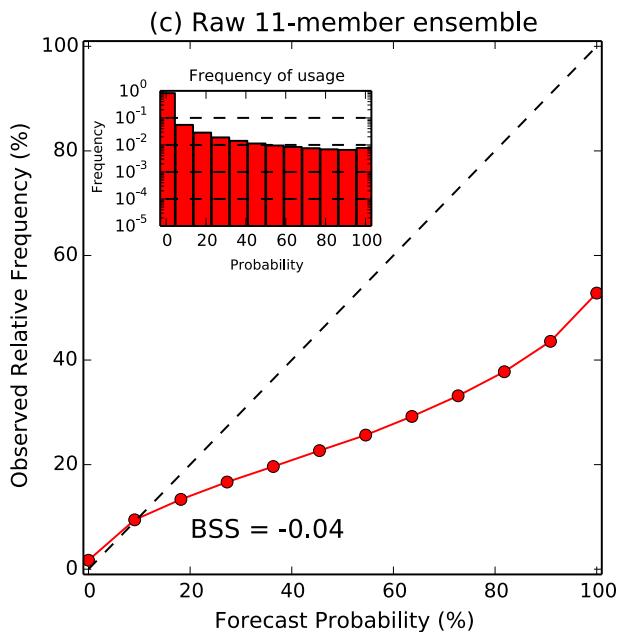
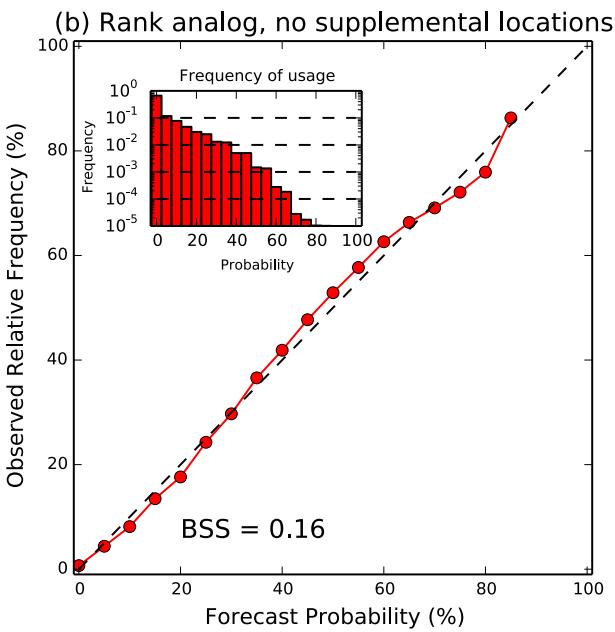
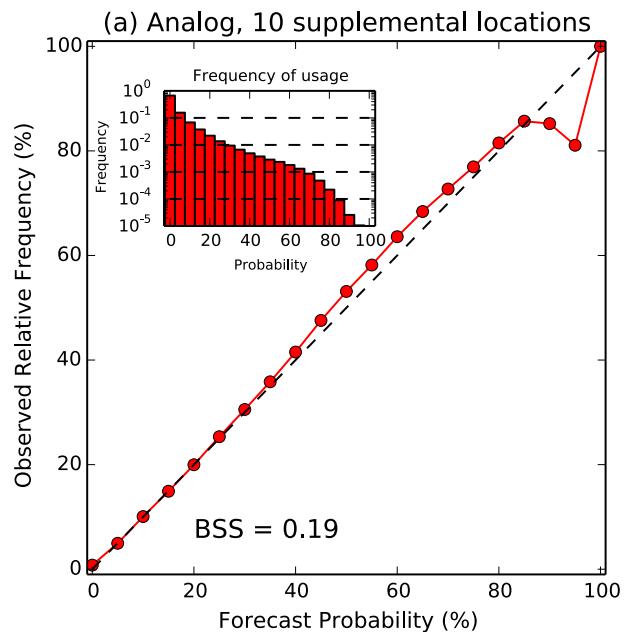
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Reliability for 060-072-h, > 25mm



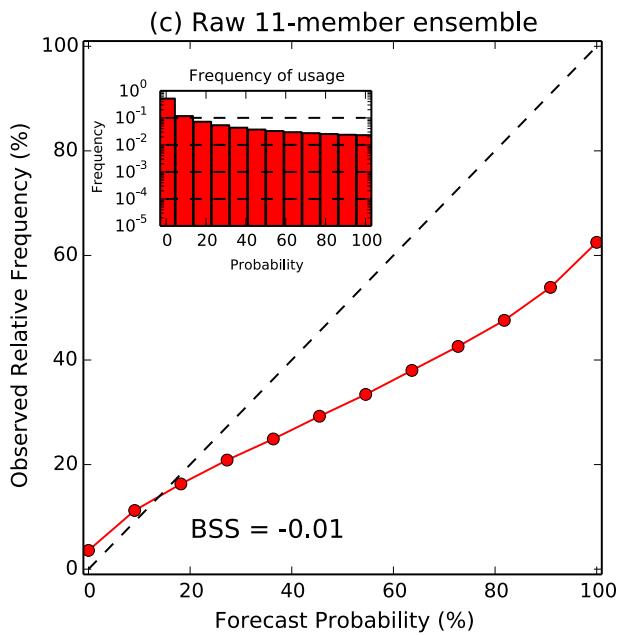
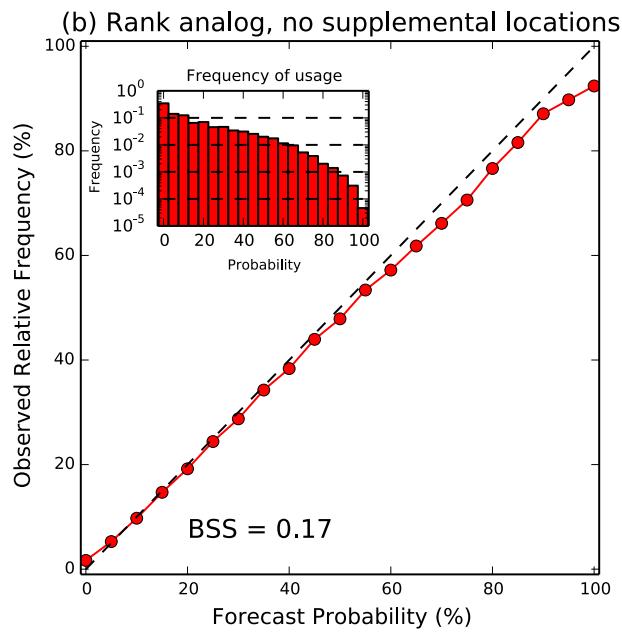
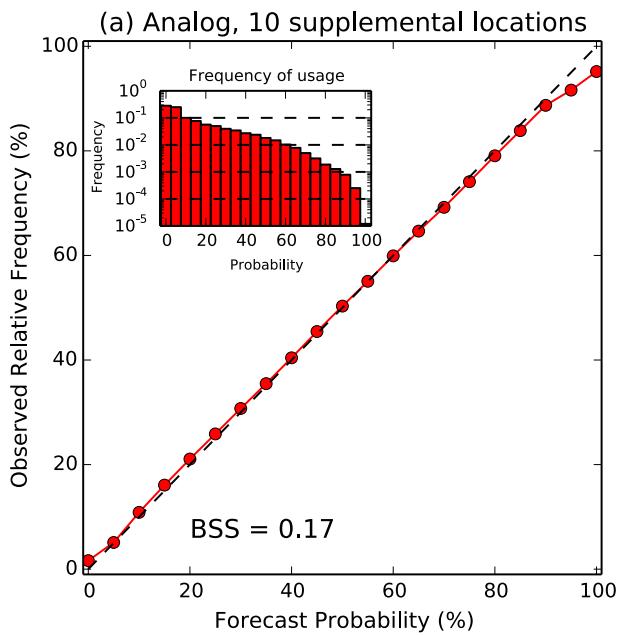
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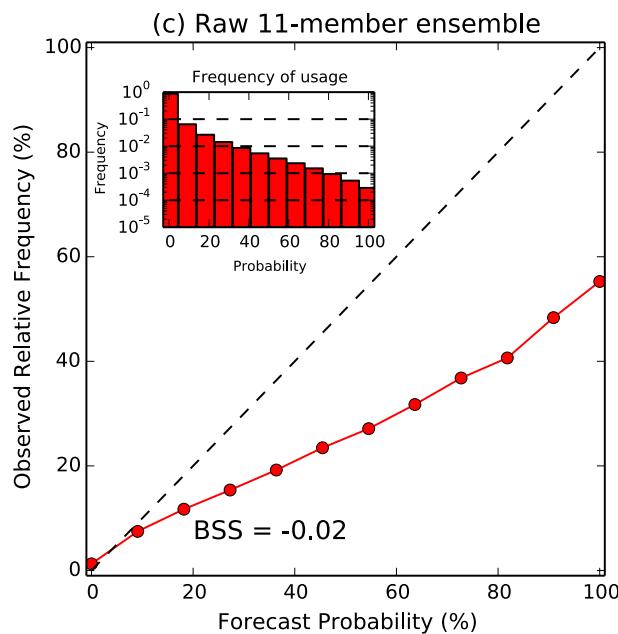
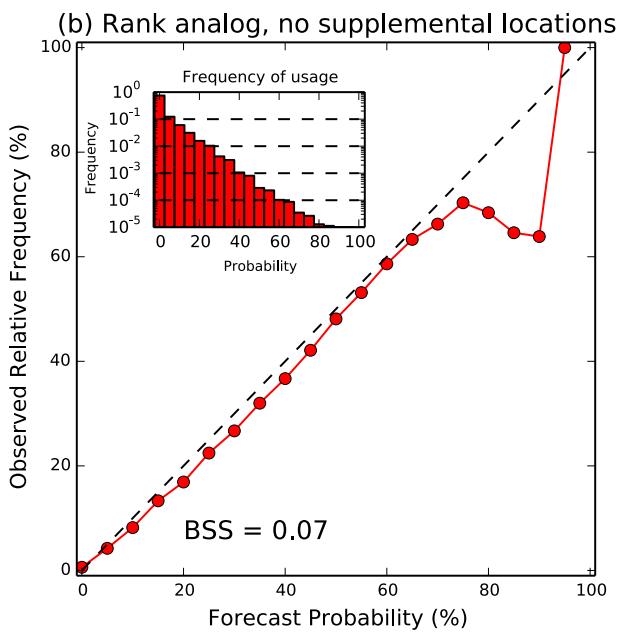
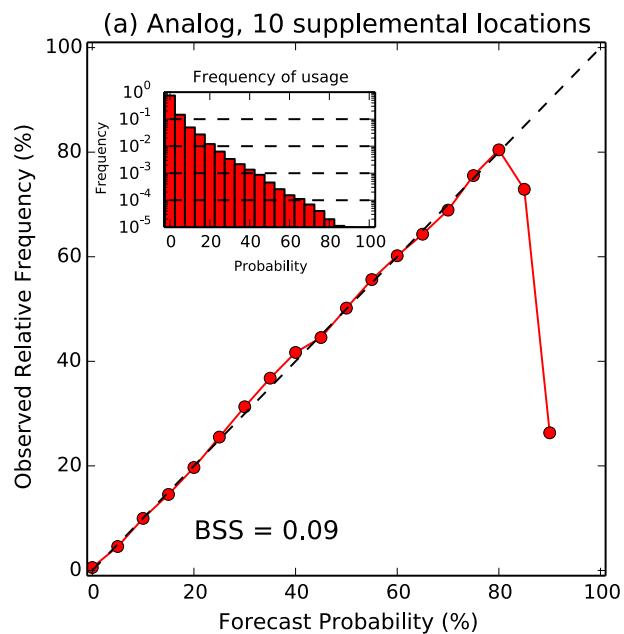
# Reliability, 108-120 h, > 1 mm

Reliability for 108-120-h, > 1mm



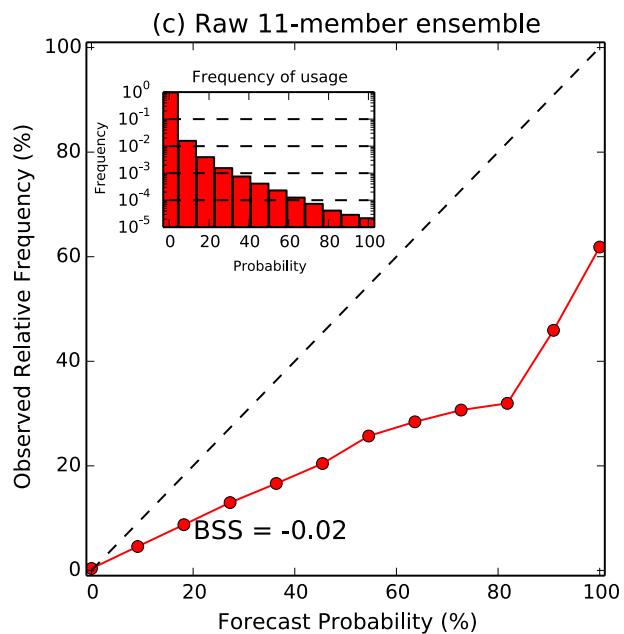
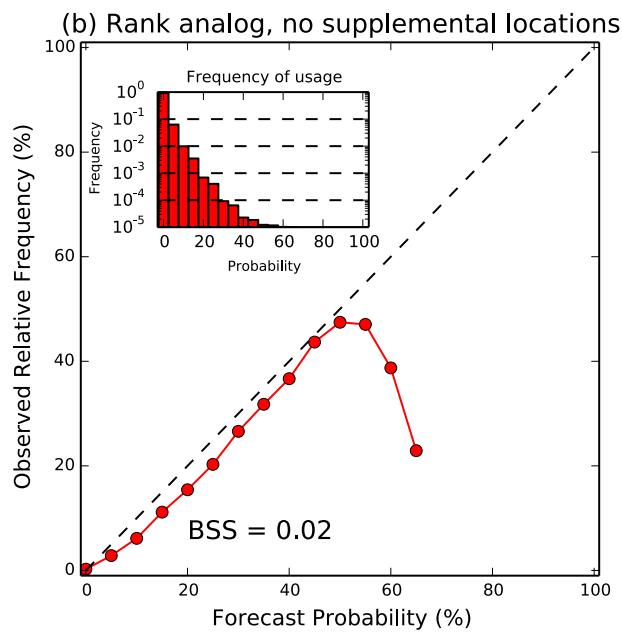
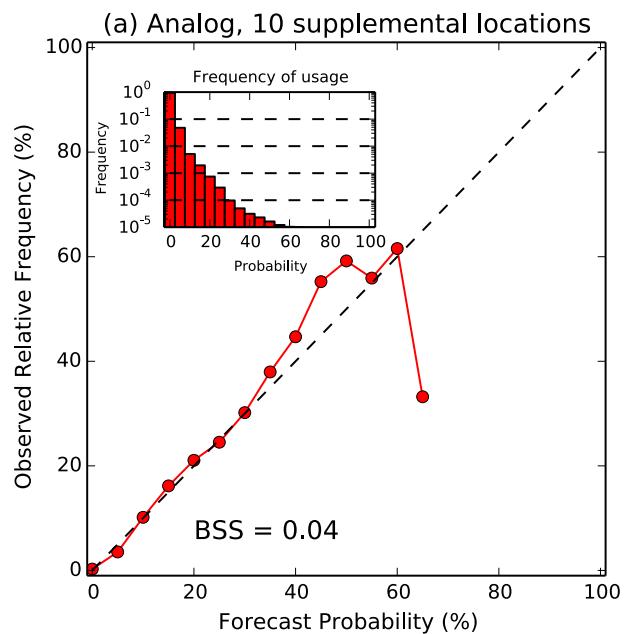
# Reliability, 108-120 h, > 10 mm

Reliability for 108-120-h, > 10mm



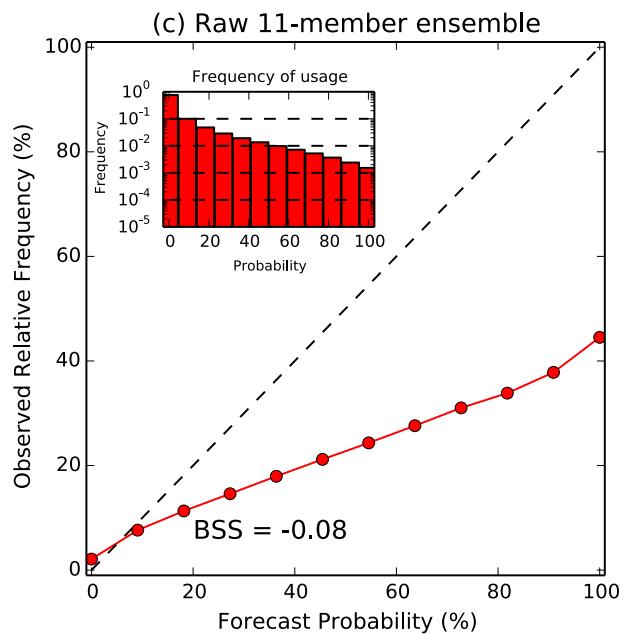
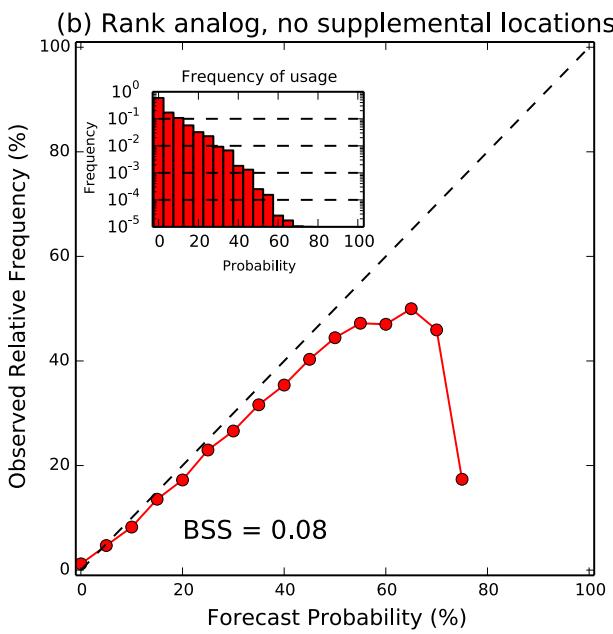
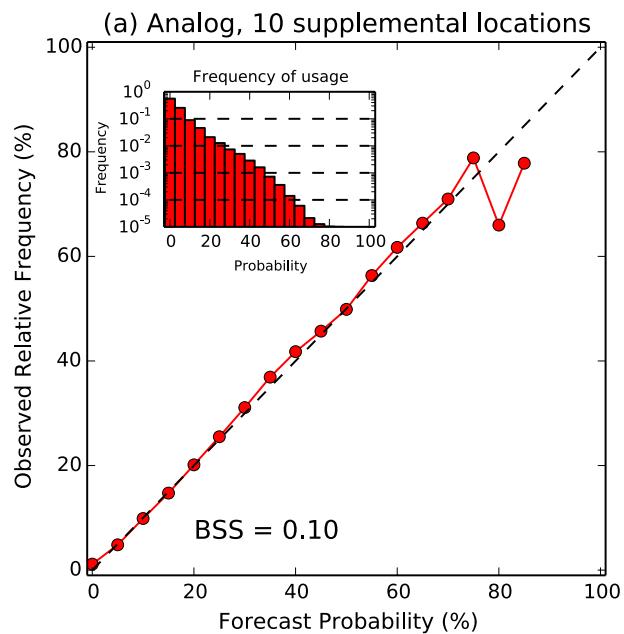
# Reliability, 108-120 h, > 25 mm

Reliability for 108-120-h, > 25mm



# Reliability, 108-120 h, > 95<sup>th</sup> percentile

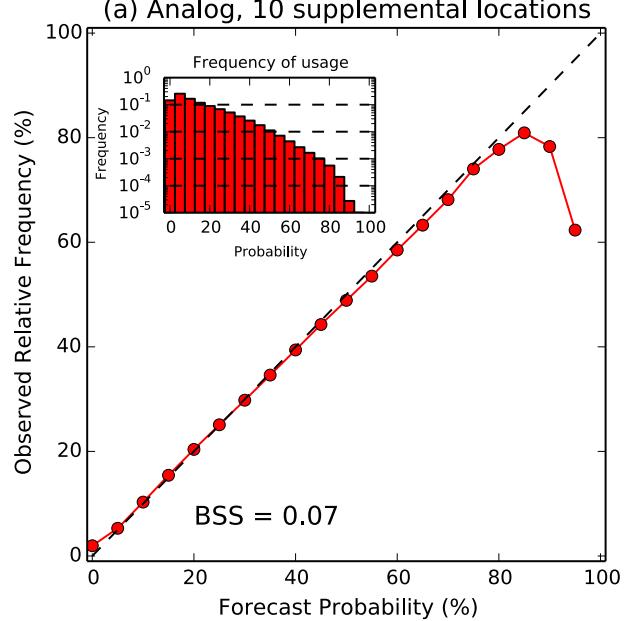
Reliability for 108-120-h, > q95



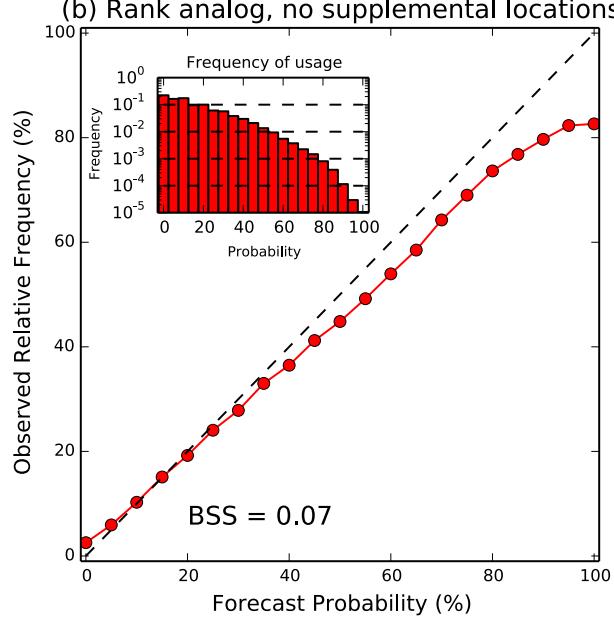
# Reliability, 156-168 h, > 1 mm

Reliability for 156-168-h, > 1mm

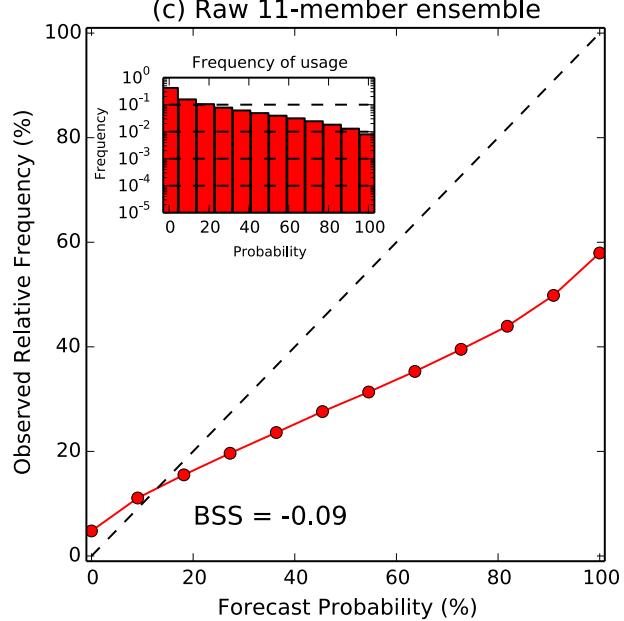
(a) Analog, 10 supplemental locations



(b) Rank analog, no supplemental locations

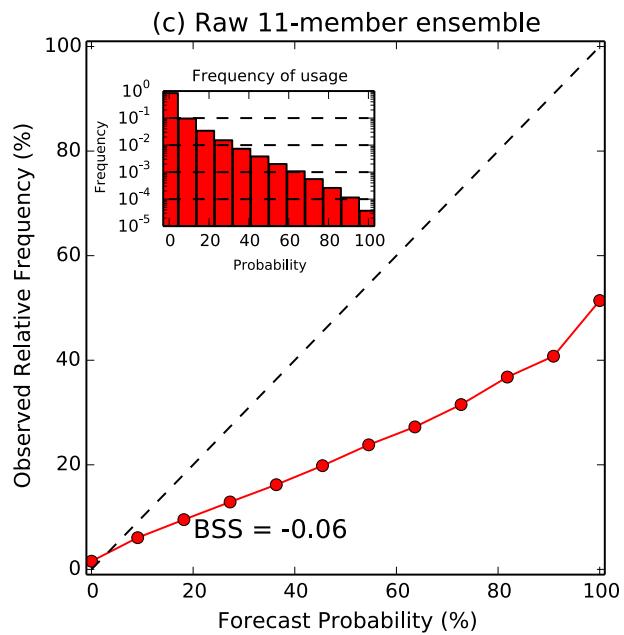
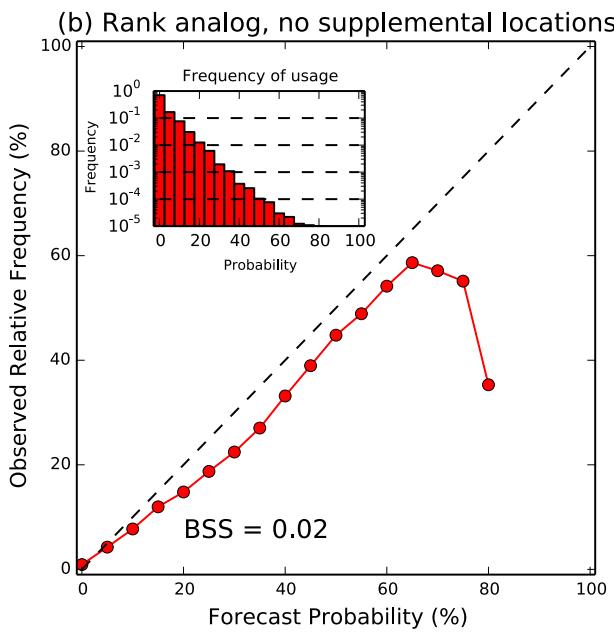
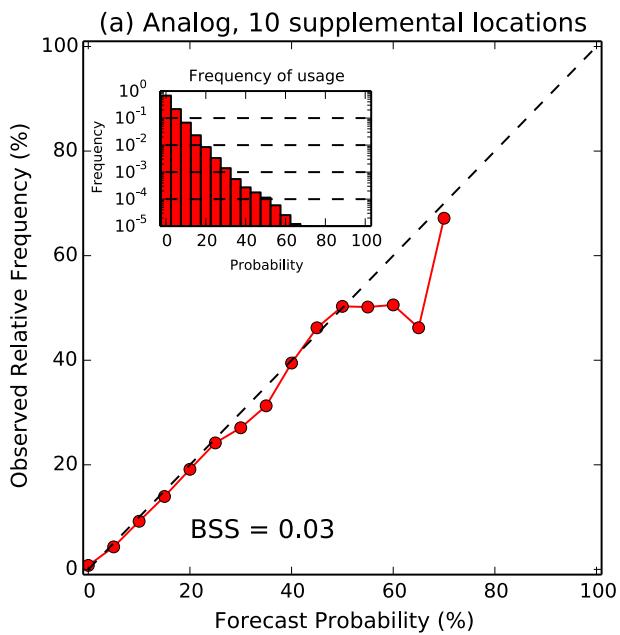


(c) Raw 11-member ensemble



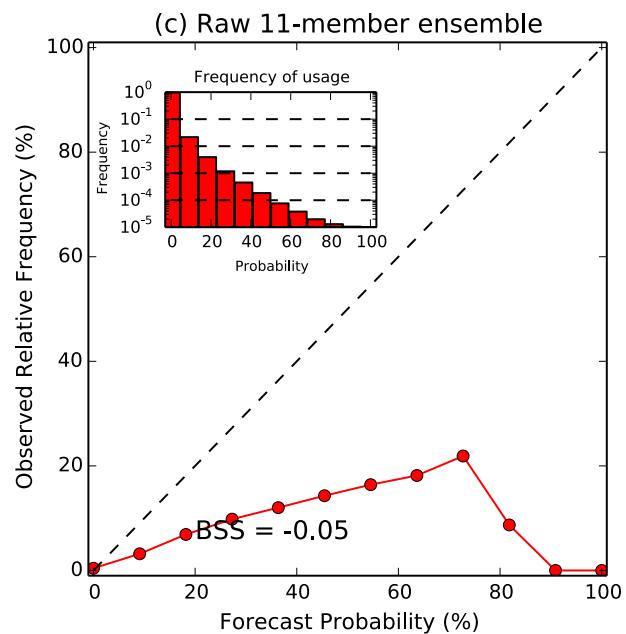
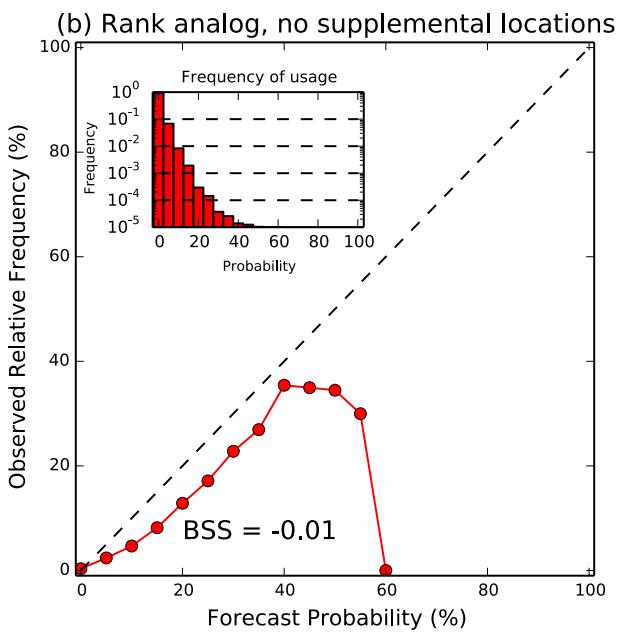
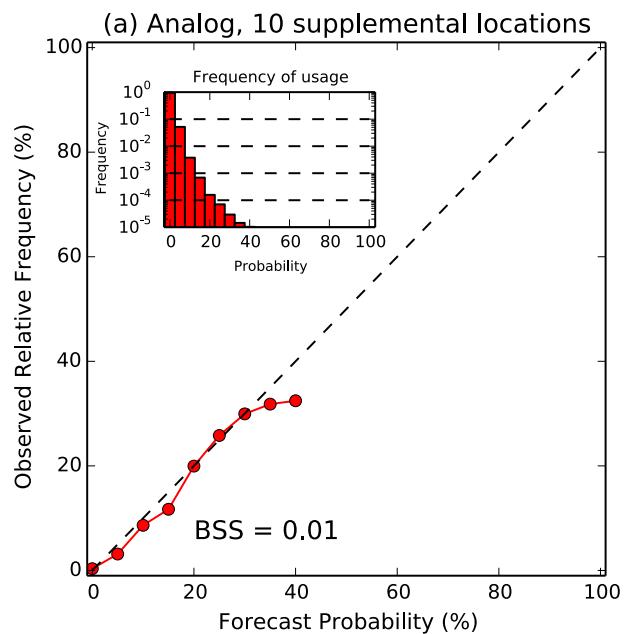
# Reliability, 156-168 h, > 10 mm

Reliability for 156-168-h, > 10mm



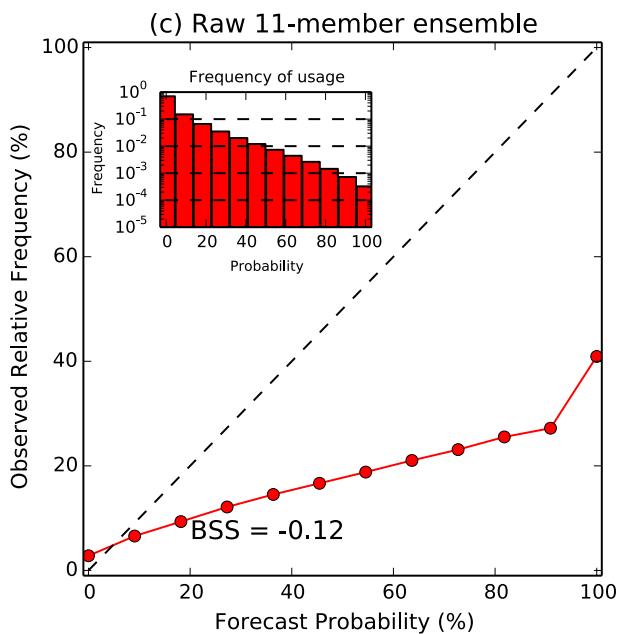
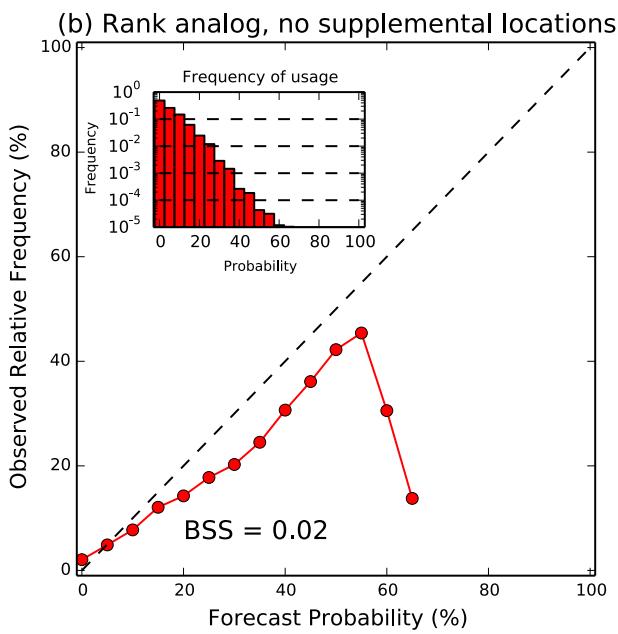
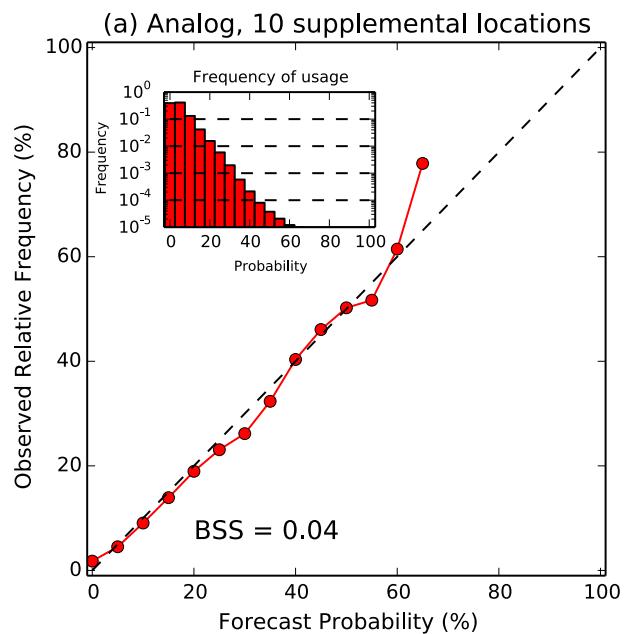
# Reliability, 156-168 h, > 25 mm

Reliability for 156-168-h, > 25mm



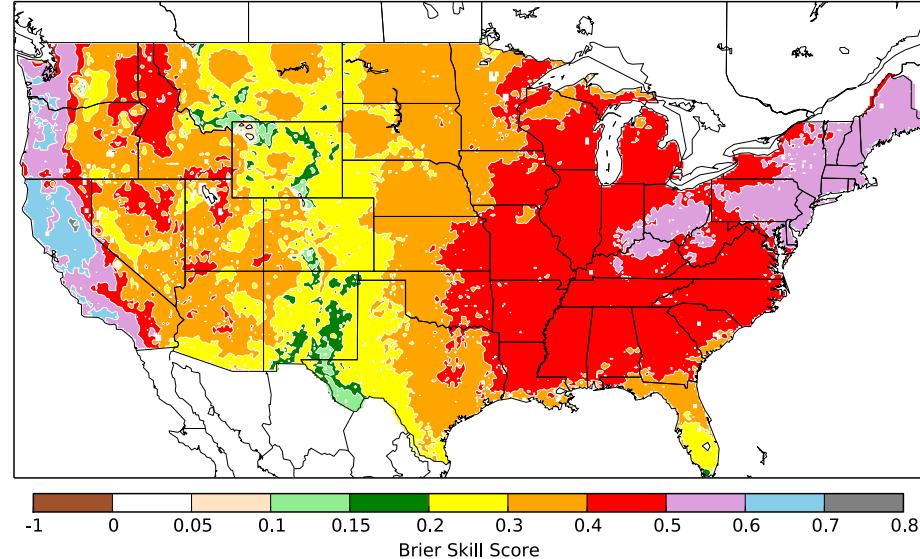
# Reliability, 156-168 h, > 95<sup>th</sup> percentile

Reliability for 156-168-h, > q95

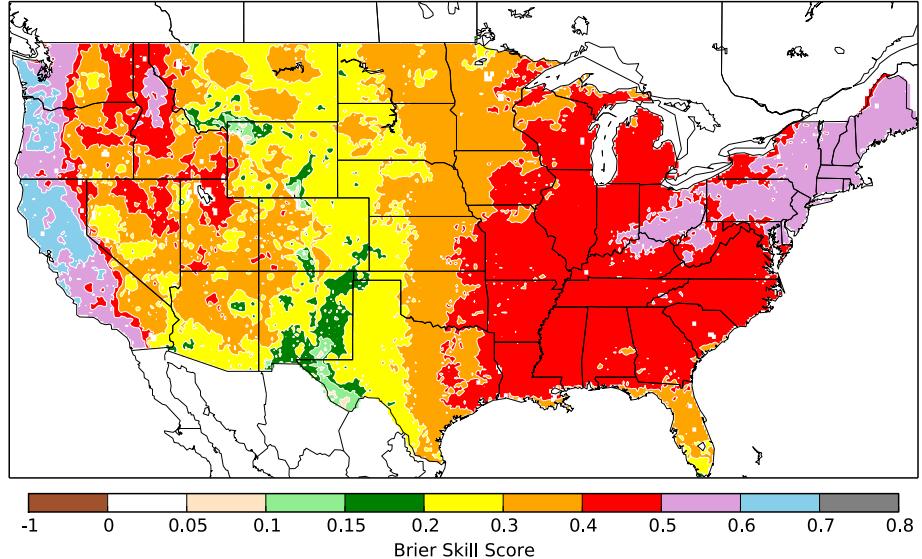


# Brier Skill Score maps, > 1 mm, 12-24 h

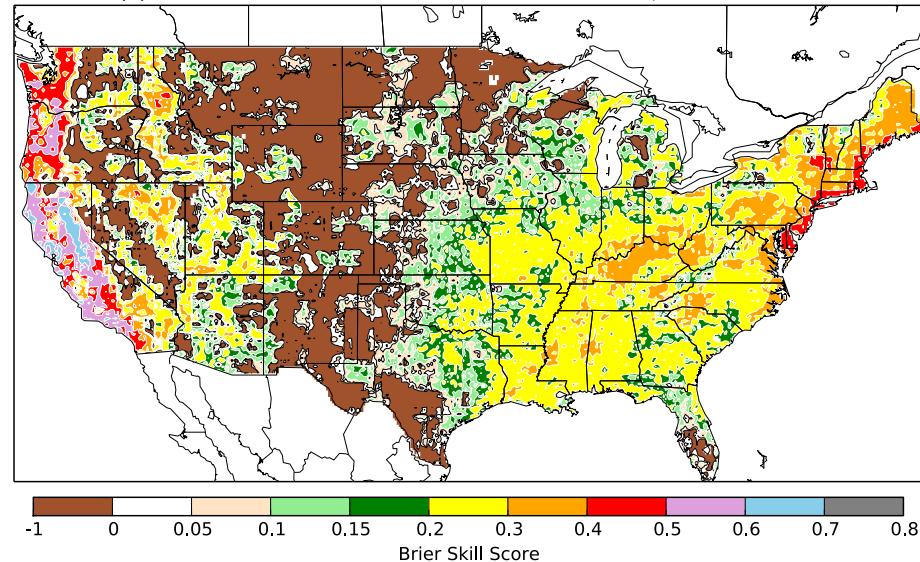
(a) BSS for 012 to 024-h analog forecast (supplemental locations), > 1mm event



(b) BSS for 012 to 024-h rank analog forecast, > 1mm event

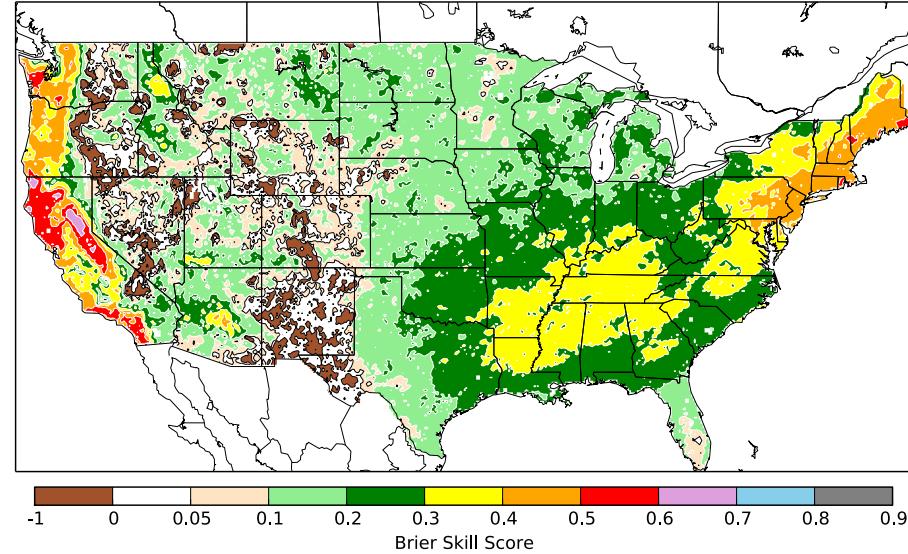


(c) BSS for 012 to 024-h raw ensemble forecast, > 1mm event

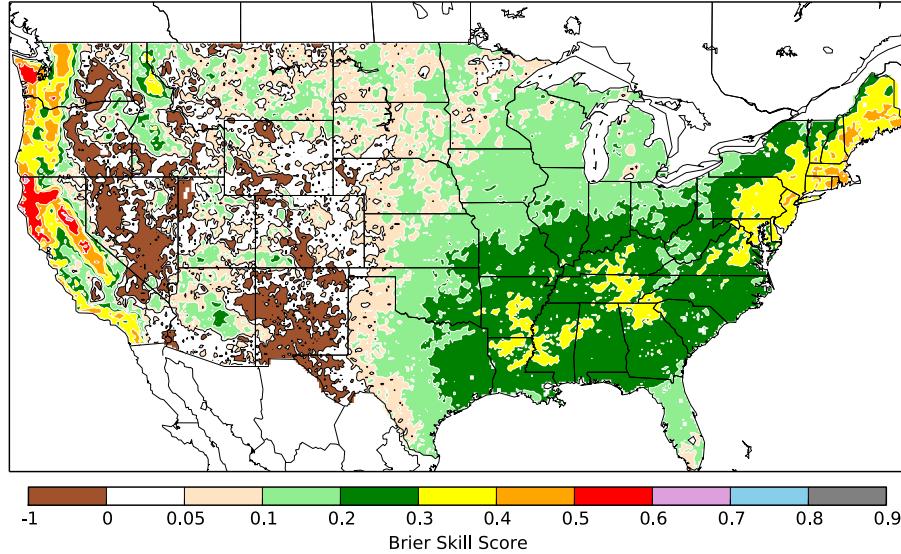


# Brier Skill Score maps, > 10 mm, 12-24 h

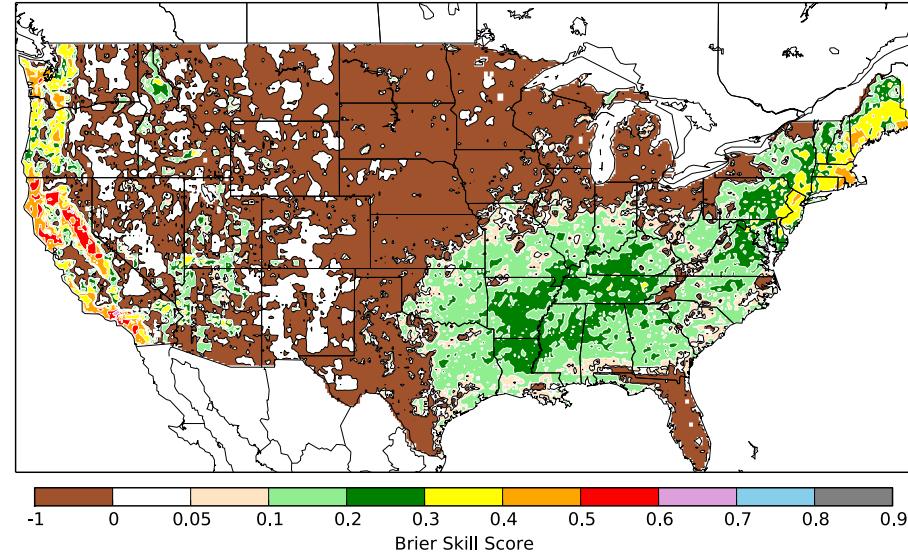
(a) BSS for 012 to 024-h analog forecast (supplemental locations), > 10mm event



(b) BSS for 012 to 024-h rank analog forecast, > 10mm event

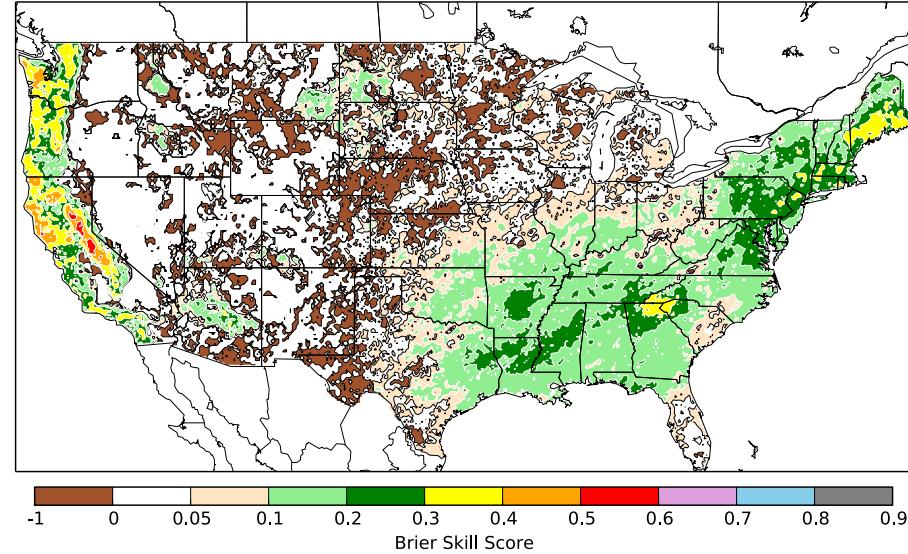


(c) BSS for 012 to 024-h raw ensemble forecast, > 10mm event

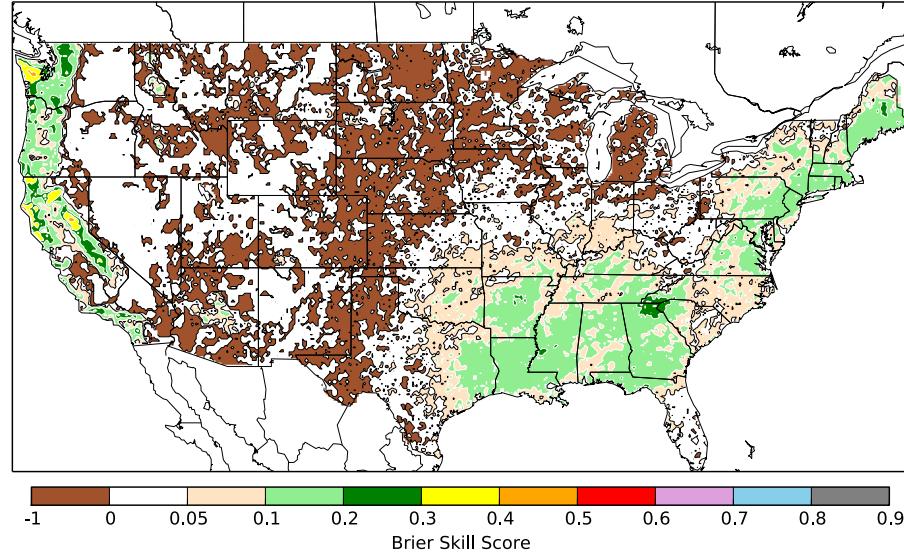


# Brier Skill Score maps, > 25 mm, 12-24 h

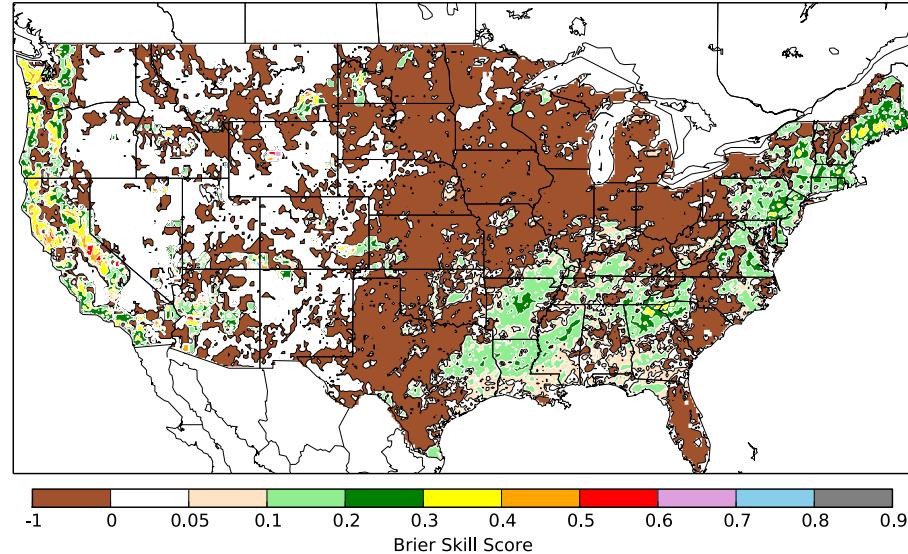
(a) BSS for 012 to 024-h analog forecast (supplemental locations), > 25mm event



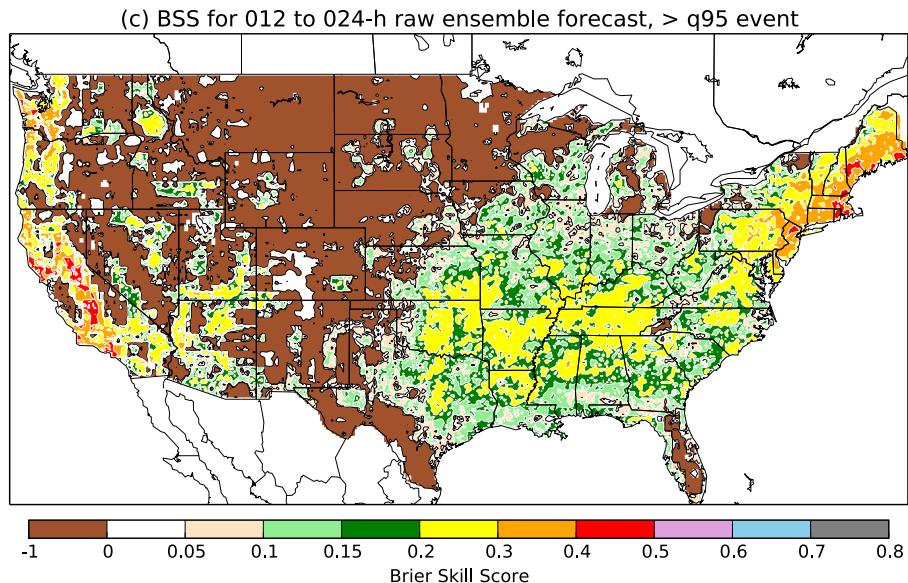
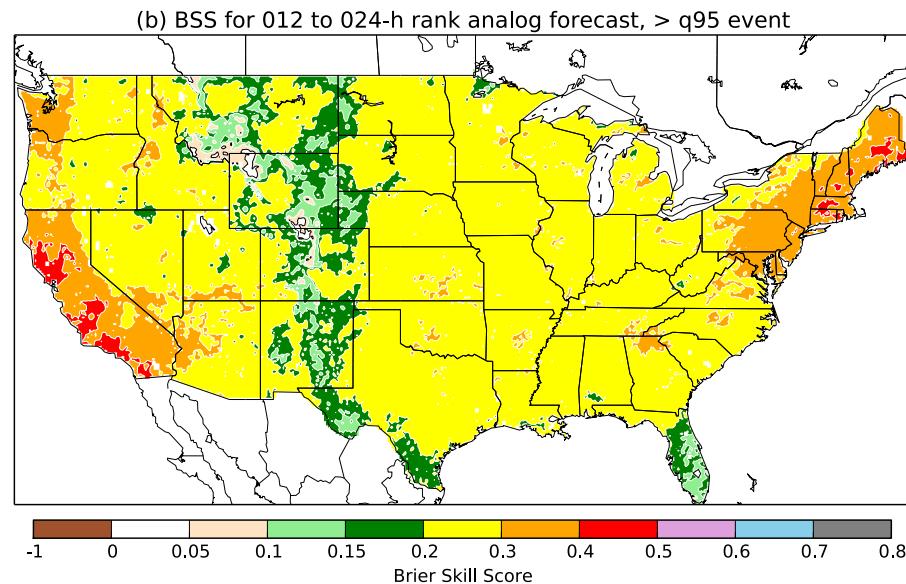
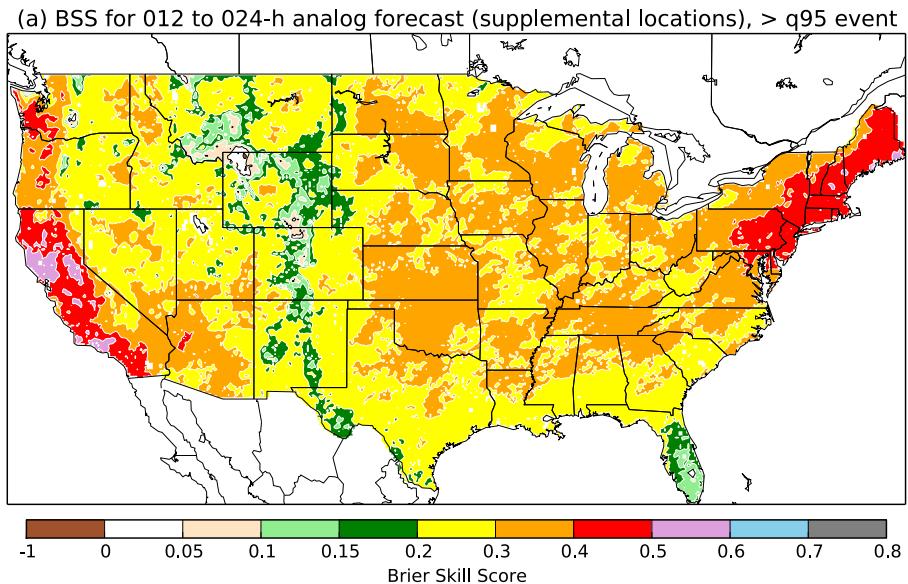
(b) BSS for 012 to 024-h rank analog forecast, > 25mm event



(c) BSS for 012 to 024-h raw ensemble forecast, > 25mm event

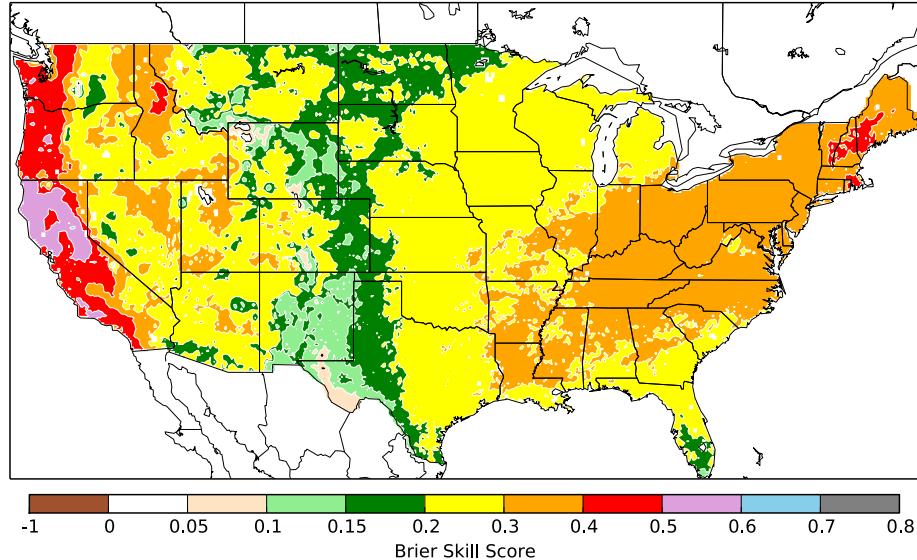


# Brier Skill Score maps, > q95, 12-24 h

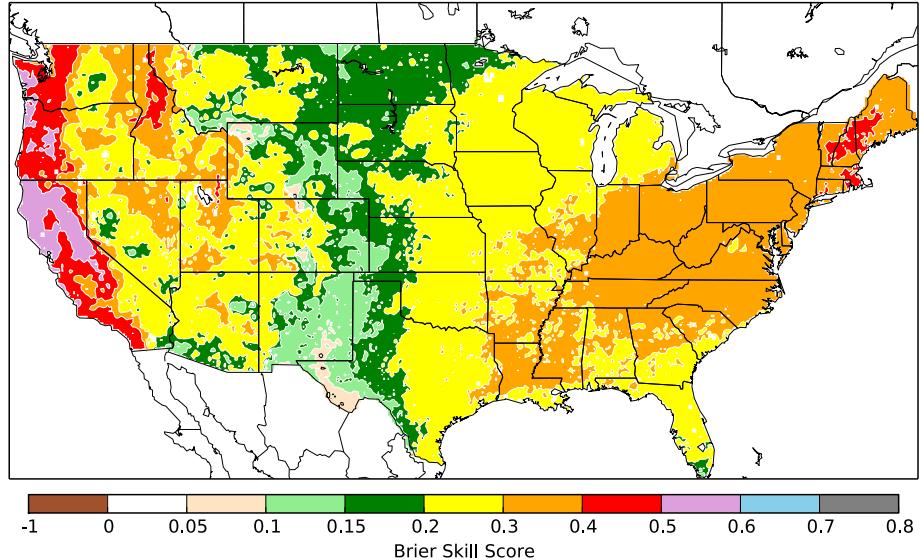


# Brier Skill Score maps, > 1 mm, 60-72 h

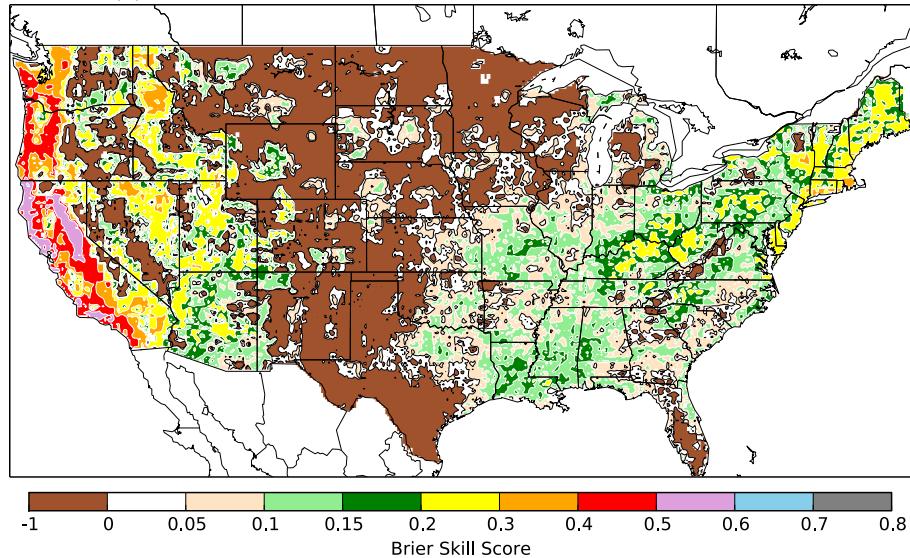
(a) BSS for 060 to 072-h analog forecast (supplemental locations), > 1mm event



(b) BSS for 060 to 072-h rank analog forecast, > 1mm event

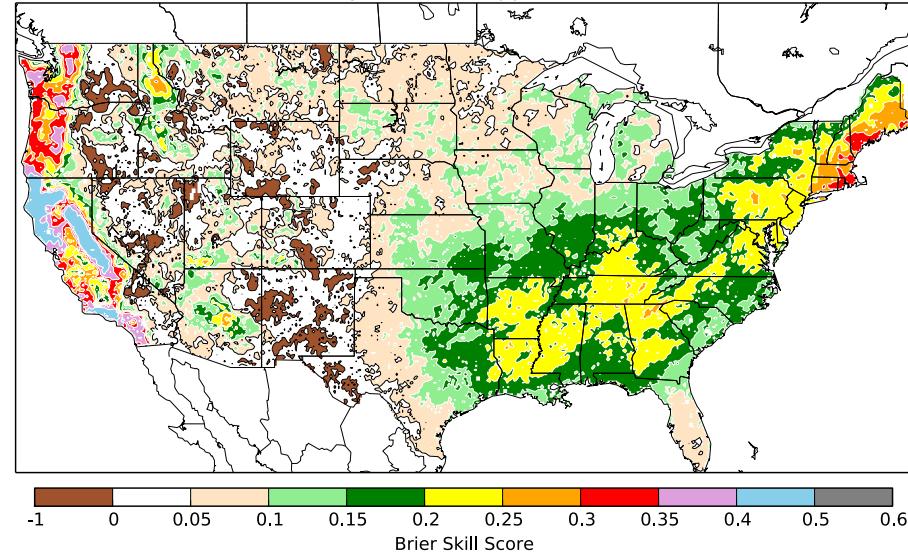


(c) BSS for 060 to 072-h raw ensemble forecast, > 1mm event

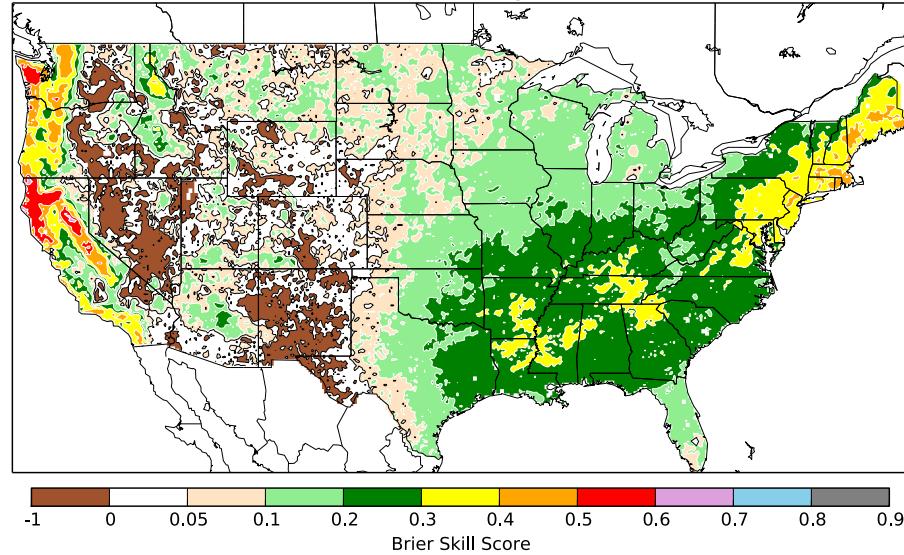


# Brier Skill Score maps, > 10 mm, 60-72 h

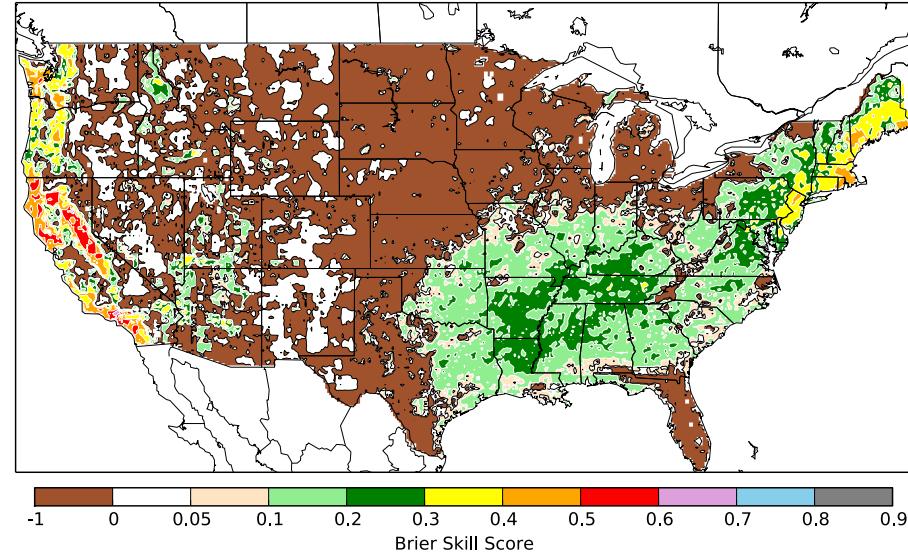
(a) BSS for 060 to 072-h analog forecast (supplemental locations), > 10mm event



(b) BSS for 012 to 024-h rank analog forecast, > 10mm event

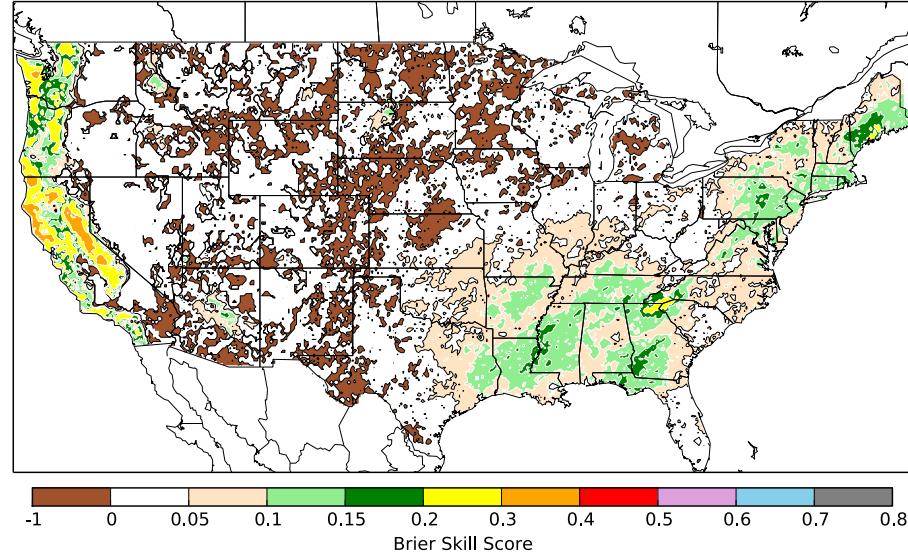


(c) BSS for 012 to 024-h raw ensemble forecast, > 10mm event

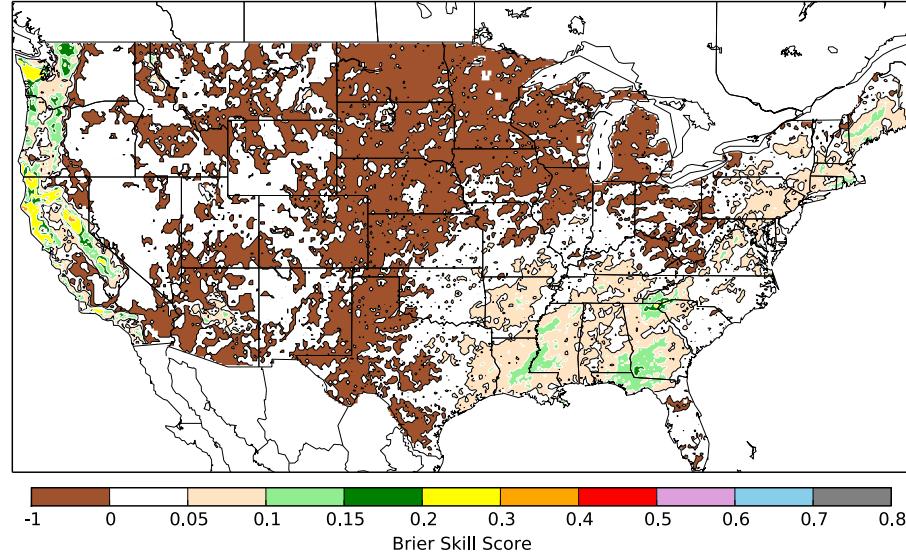


# Brier Skill Score maps, > 25 mm, 60-72 h

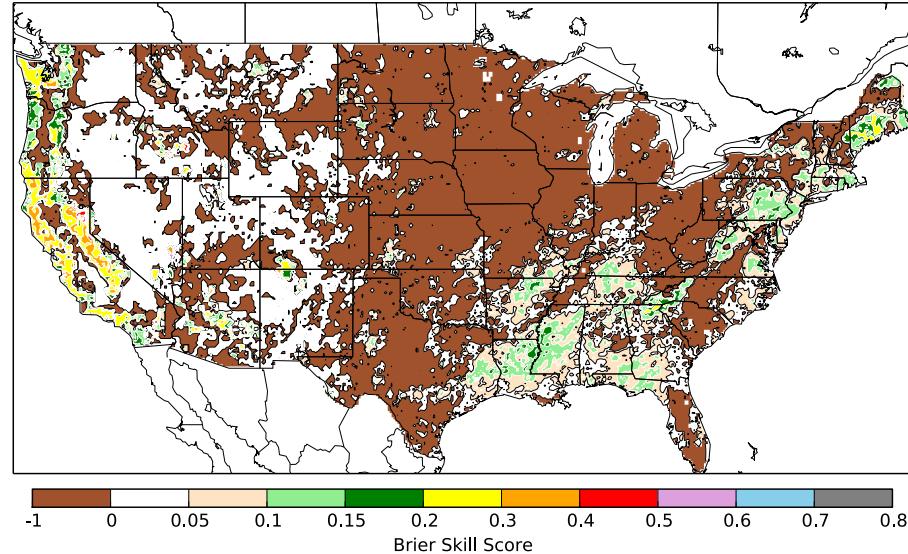
(a) BSS for 060 to 072-h analog forecast (supplemental locations), > 25mm event



(b) BSS for 060 to 072-h rank analog forecast, > 25mm event

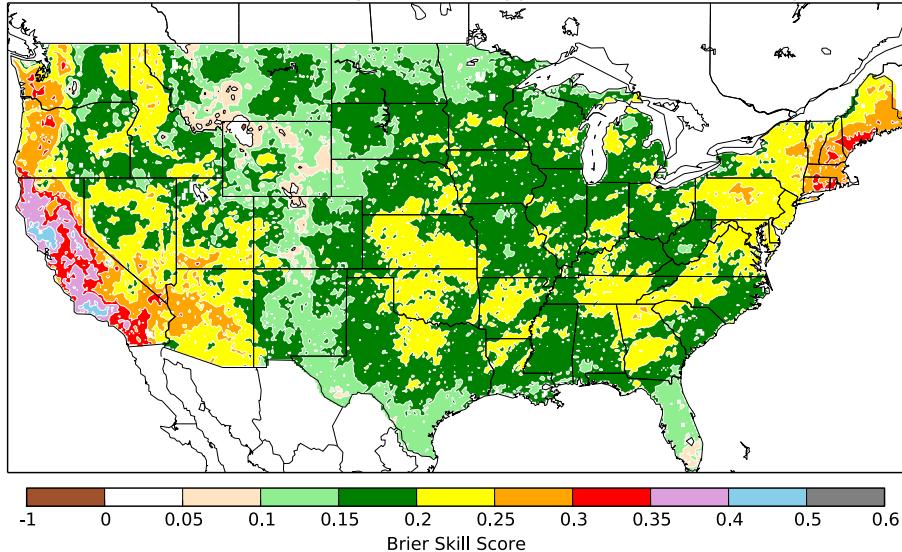


(c) BSS for 060 to 072-h raw ensemble forecast, > 25mm event

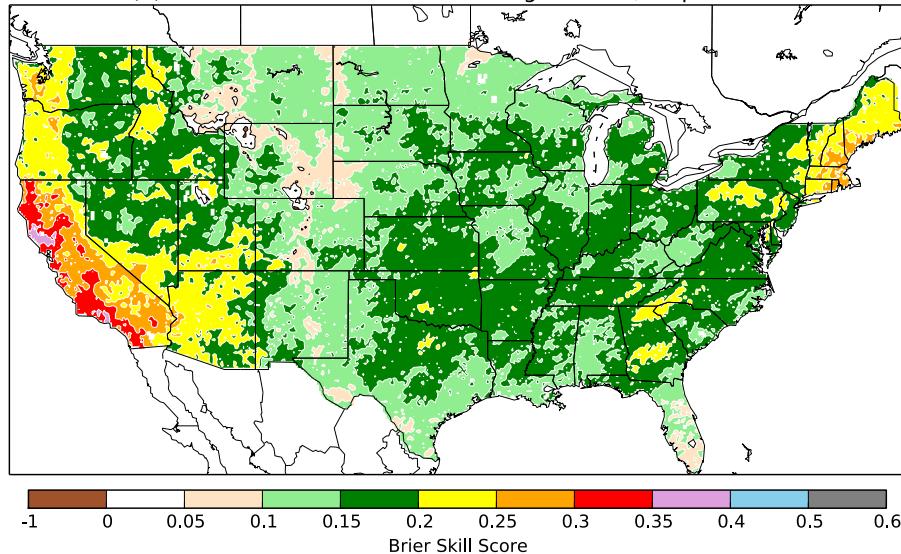


# Brier Skill Score maps, > q95, 60-72 h

(a) BSS for 060 to 072-h analog forecast (supplemental locations), > q95 event



(b) BSS for 060 to 072-h rank analog forecast, > q95 event



(c) BSS for 060 to 072-h raw ensemble forecast, > q95 event

